LEVEL II

A075 970

Annual Technical Report PATR-1069-79-6
Contract No. N000-14-78-C-0495
June, 1979

DEVELOPMENT OF A DECISION TAXONOMY FOR THE MARINE COMMAND AND CONTROL ENVIRONMENT

VOLUME I

BY

ALAIN CROLOTTE
JOSEPH SALEH

Prepared For:

OFFICE OF NAVAL RESEARCH
800 North Quincy Street
Arlington, Virginia 22217

PERCEPTRONICS

6271 VARIEL AVENUE • WOODLAND HILLS • CALIFORNIA 91367 • PHONE (213) 884-7470

NOTES

(12)

Annual Technical Report PATR-1069-79-6
Contract No. N000-14-78-C-0495
June, 1979

DEVELOPMENT OF A DECISION TAXONOMY FOR THE MARINE COMMAND AND CONTROL ENVIRONMENT

VOLUME I

BY

ALAIN CROLOTTE
JOSEPH SALEH

Prepared For:

OFFICE OF NAVAL RESEARCH
800 North Quincy Street
Arlington, Virginia 22217

PERCEPTRONICS

6271 VARIEL AVENUE • WOODLAND HILLS • CALIFORNIA 91367 • PHONE (213) 884-7470

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (14) PATR-1069-79-6 - V, I	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Development of a Decision Taxonomy for the Marine Command and Control Environment.		5. TYPE OF REPORT & PERIOD COVERED Annual Technical Report 7/1/78 - 6/30/79
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) Alain Crolotte [redacted] Joseph Saleh	(15)	8. CONTRACT OR GRANT NUMBER(s) N00014-78-C-0495
9. PERFORMING ORGANIZATION NAME AND ADDRESS Perceptronics, Incorporated 6271 Variel Avenue Woodland Hills, CA 91367		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research 800 North Quincy Street Arlington, Virginia 22217	(11)	12. REPORT DATE June 1979
		13. NUMBER OF PAGES (12) 168
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Unlimited Distribution

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

1 Jul 78-30 Jun 79

18. SUPPLEMENTARY NOTES

Approved by:

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Marine Amphibious Brigade	Functional Requirement	Degree of Plausibility
Decision Making	Decision Maker Attribute	Aiding Score
Decision Task	Decision Aiding Technique	Suitability Score
Information Requirement	Decision Aid Feature	
Decision Task Attribute	Degree of Compatibility	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A decision aid selection methodology for the ~~MAB~~ decision making environment is presented. Built around a three-way taxonomy, the methodology allows the user to define a degree of merit for each decision aid with respect to a given decision situation.

The MAB decision-making environment is first analyzed and the decision tasks pertaining to this environment identified. Decision tasks are then classified along three sets of descriptors: (1) information requirements, (2) attributes,

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

290285

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) and (3) functional requirements. Clusters of decision tasks with common characteristics are identified which leads to the MAB decision task taxonomy.

Decision maker characteristics are identified, and the characteristics of potential MAB decision makers are analyzed, yielding the MAB decision maker taxonomy. The main finding is that decision aids cannot be tailored for individual decision makers, but rather should be adaptive to a number of decision-maker characteristics. Decision task taxonomy and decision maker taxonomy together constitute the decision situation taxonomy.

Decision aids are classified along three sets of descriptors: (1) decision-aiding technique(s), (2) features, and (3) costs. While the various classes generated by (1) and (2) constitute the decision aid taxonomy, costs are treated separately. Via relevance matrices, a set of matching principles is devised to line the three dimensions of the taxonomy. The methodology gives a specific procedure for calculating the degree of merit of a decision aid with respect to a given decision situation. By dividing this degree of merit by the decision aid cost, a cost benefit measure for each decision aid is computed.

TABLE OF CONTENTS

		Page
1.	INTRODUCTION	1-1
	1.1 Overview	1-1
	1.2 Objectives	1-1
	1.3 Method of Approach	1-2
	1.4 Summary	1-5
2.	THE MARINE AMPHIBIOUS BRIGADE DECISION-MAKING ENVIRONMENT	2-1
	2.1 Introduction	2-1
	2.2 The MAB Environment	2-1
	2.2.1 Marine Amphibious Brigade	2-1
	2.2.2 Amphibious Operation	2-5
	2.2.3 Staff Organization and Techniques	2-6
	2.2.4 Doctrinal Publications	2-8
	2.2.5 The MTACC Systems	2-14
	2.3 Decision Task Identification	2-15
	2.3.1 Organization	2-15
	2.3.2 Decision-Task Identification Methodology	2-16
	2.3.3 Decision-Task Identification	2-17
	2.4 Insights and Findings	2-28
3.	DECISION TASK TAXONOMY	3-1
	3.1 Overview	3-1
	3.2 Information Requirements	3-1
	3.3 Decision-Task Attributes	3-4
	3.4 Functional Requirements	3-7
	3.5 Classification of Decision Tasks	3-7
	3.6 Interview Results	3-13
	3.7 MAB Decision Task Clusters	3-21
4.	DECISION MAKER TAXONOMY	4-1
	4.1 Overview	4-1
	4.2 Decision Style	4-1
	4.3 Decision-Maker Attributes	4-3
	4.4 Conclusions	4-6

TABLE OF CONTENTS (CONTINUED)

	Page
5. DECISION AID TAXONOMY	5-1
5.1 Approach	5-1
5.2 Decision-Aiding Techniques	5-5
5.2.1 Overview	5-5
5.2.2 Decision Analysis	5-6
5.2.3 Operations Research	5-12
5.2.4 Computer Science	5-13
5.3 Definition of Plausible Decision Aids	5-16
5.4 Decision Aid Characteristics	5-20
5.4.1 Overview	5-20
5.4.2 Decision-Aiding Techniques as Decision-Aid Characteristics	5-21
5.4.3 Decision-Aid Features	5-21
5.4.4 Decision-Aid Costs	
6. MATCHING PRINCIPLES	6-1
6.1 Overview	6-1
6.2 Aiding Score	6-2
6.2.1 Overview	6-2
6.2.2 Plausibility Degree	6-2
6.2.3 Compatibility Degree	6-4
6.3 Suitability Score	6-5
6.4 Selecting a Decision Aid	6-5
6.5 Example of Application	6-6
7. CONCLUSIONS	7-1
8. REFERENCES	8-1
APPENDIX A	A-1
APPENDIX B	B-1
APPENDIX C	C-1

1. INTRODUCTION

1.1 Overview

The present report summarizes the work accomplished by Perceptronics during a one-year research and development effort to develop a usable taxonomy of Marine Amphibious Brigade (MAB) command and control decisions. This project, planned within the framework of a three-year program, provides a base-line for a systematic approach to the design and/or selection of suitable decision aids to improve tactical decision making in the Marine Corps.

The report is divided into six chapters, each documenting a phase of the effort. The MAB decision-making environment is described in Chapter 2, while the MAB decision task taxonomy is the object of Chapter 3. Decision maker and decision aid taxonomies are described in Chapters 4 and 5 respectively, while the use which can be made of the taxonomies in selecting decision aids is illustrated in Chapter 6.

1.2 Objectives

The major goals of the program are:

(1) To develop a usable framework for selection of effective decision aids for the MAB command and control environment.

(2) To select and implement a decision aid based on the above framework.

(3) To demonstrate and evaluate the decision aid using a realistic MAB scenario.

The first year effort was aimed at the first major goal and was attained through the accomplishment of the following:

(1) Analysis of the MAB command and control environment and development of a taxonomy of decision situations oriented toward the selection of appropriate decision-aiding techniques.

(2) Establishment of a usable taxonomy of decision aids for the MAB environment.

(3) Establishment of a set of matching principles to link all MAB decision situations with proper decision aids.

The major products of the effort are (1) a detailed database of MAB decision tasks with their respective functional requirements, attributes and information requirements, and (2) a well-defined methodology for selection of effective decision aids for any specific decision situation in the MAB command and control environment.

1.3 Method of Approach

The general method of approach consisted of four phases: (1) development of a taxonomy of MAB decision tasks, (2) development of a taxonomy of MAB decision makers, (3) development of a taxonomy of decision aids and (4) development of a decision aid selection methodology based on the taxonomies developed.

The decision task taxonomy development effort itself consisted of two phases: (1) identification and classification of decision tasks encountered within the MAB decision-making environment, and (2) validation of the results by Marine Corps personnel experienced in operations.

During a preliminary visit to Camp Pendleton, personnel from the Marine Corps Tactical System Support Activity (MCTSSA) were interviewed. It was then assessed that the Marine Corps doctrine should be used as the main source of information for the analysis, and a list of documents which could be used for the decision task taxonomy phase was suggested by the interviewed Marine Corps personnel. Two types of sources were actually identified: (1) Marine Corps doctrinal publications, and (2) research and development publications related to MCTSSA projects.

The identification of decision tasks, performed using the method described in Chapter 3, resulted in a list of decision tasks identified by decision-making keywords. Each decision task was then analyzed in terms of its information requirements, relevant attributes and functional requirements.

Validation of the results of the performed analysis of the MAB decision-making environment was then sought from Marine Corps experts. For the decision-task identification process, direct verification of the results obtained (i.e., of the list of decision tasks) was performed via interview. Validation of the results of decision-task classification, according to information requirements and relevant attributes, was later sought via a structured interview.

Functional requirements, however, were addressed in quite a different manner. Functional requirements are defined as the various steps a decision maker could go through to perform the task from a decision analytic standpoint. They are totally independent from information requirements and decision-task attributes, and unlike these characteristics they require, for proper classification, extensive training in decision analysis. Identification of functional requirements, therefore, was based on the investigation performed by decision analysis experts.

For the decision maker taxonomy phase, a number of technical papers and reports were selected and analyzed, thus leading to a preliminary set of decision-maker characteristics. Via interview, this set was later refined and a final set of decision maker attributes, which hinge on decision task performance, was identified. The relationships existing among various decision-maker attributes were then obtained. The major conclusion of the analysis was that while certain attributes are very hard to relate to decision-task functional requirements in a quantifiable manner, the other attributes take random values. Consequently, decision aids for the MAB decision-making environment cannot be tailored for specific decision maker attributes and must be adaptive to various potential users.

The decision aid taxonomy effort started with a review and critique of past and on-going efforts related to decision aid selection. Our approach was to define two types of decision-aid descriptors. The first type is related to the type of decision-aiding technique(s) the decision aid employs, while the second relates to the implementation of this technique which is utilized by the decision aid. Implementation-oriented characteristics in turn fall into two categories: (1) features and (2) costs.

As a first step toward a workable decision aid taxonomy, a hierarchical list of decision-aiding techniques was devised. All potential decision-aiding techniques were included, even those which are only promising as opposed to well-established techniques having already led to the development of actual decision aids. These aiding techniques relate to decision-task attributes and functional requirements via relevance matrices. Similarly, decision-aid features relate to decision-task attributes via a relevance matrix, while costs are treated separately.

Using the relevance matrices mentioned above, a set of matching principles was devised. Given a decision situation, an aiding score, associated with the decision-aiding technique employed, can be defined. The aiding score is an aggregate of a plausibility degree relating to functional requirements, and of a compatibility degree relating to decision-task attributes. Similarly, a suitability score measuring how well the decision-aid features match the decision-task attributes was defined. By aggregation of aiding and suitability scores, we obtain a matching score which measures how appropriate a decision aid is in a given decision situation. After costs have been estimated, a cost effectiveness measure is obtained, thus allowing us to evaluate and compare decision aids for a particular decision situation.

1.4 Summary

The work accomplished during the first program year, depicted in Figure 1-1, is described in the following:

(1) A methodology for the identification of decision tasks was selected. It provides for the separation of decision-related tasks from procedural non-decision tasks within the MAB environment.

(2) A technical interview of personnel in charge of the Marine Tactical Command and Control Systems (MTACCS) development at the Marine Corps Tactical Systems Support Activity (MCTSSA), Camp Pendleton was conducted. As part of the interview, the required documentation for conducting the study was identified.

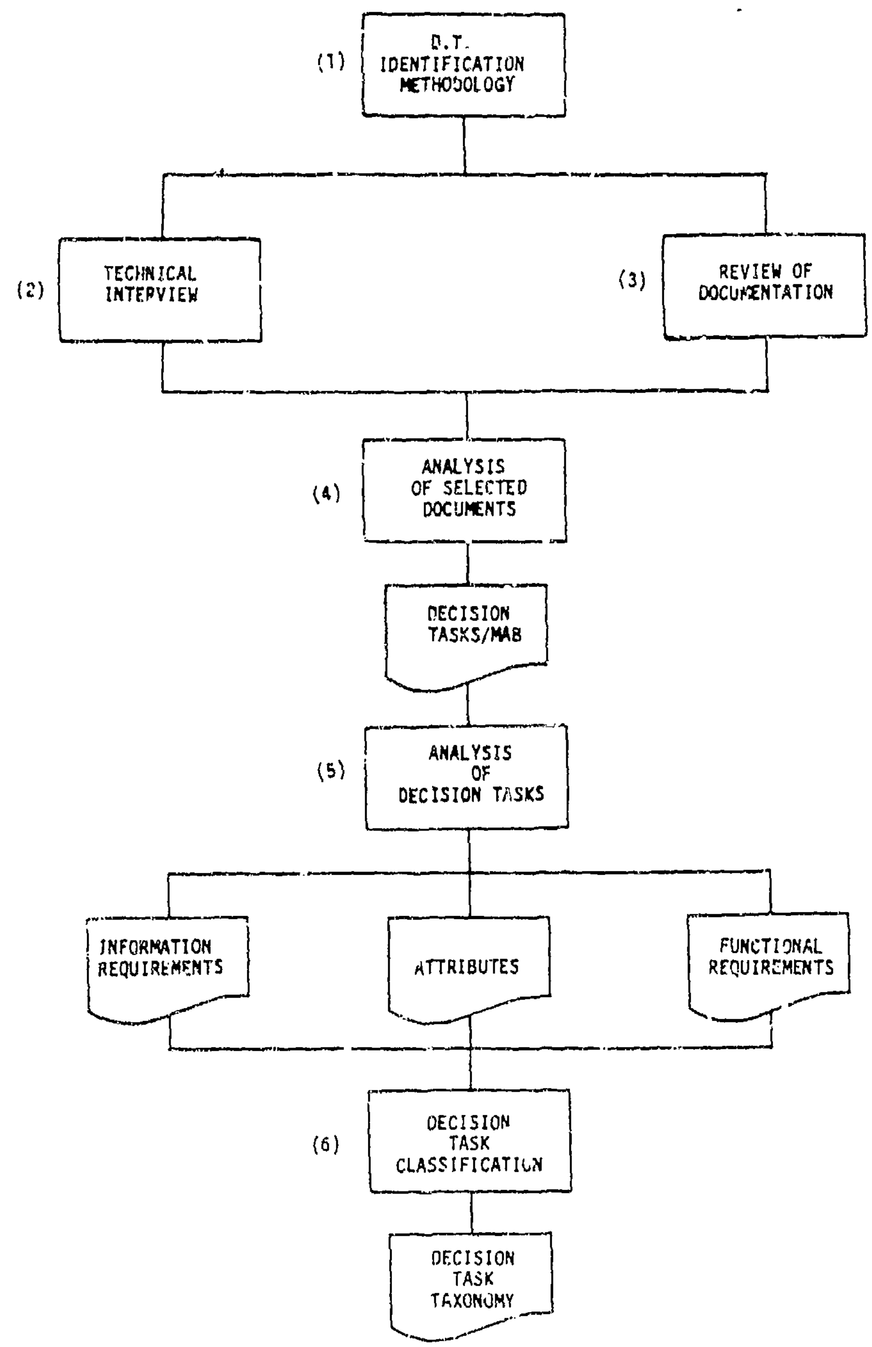


FIGURE 1-1.
WORK FLOW DURING FIRST PROGRAM YEAR

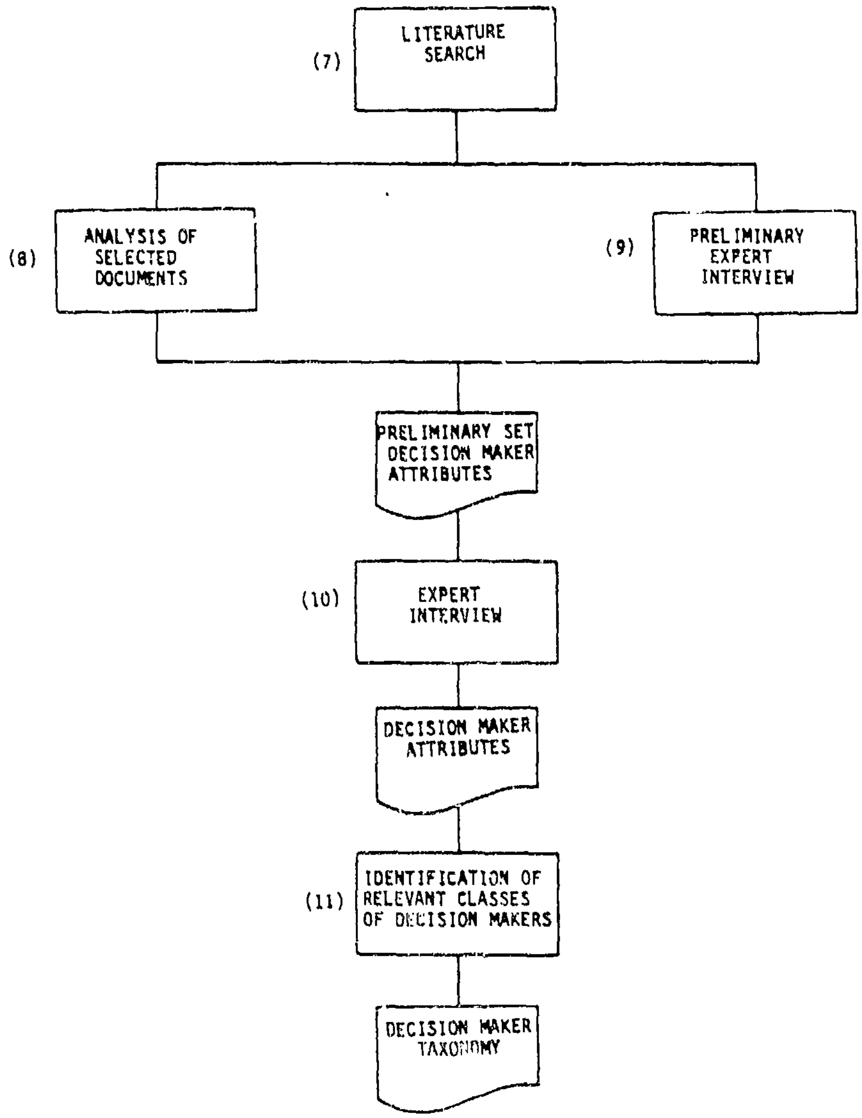


FIGURE 1-1 (CONTINUED)

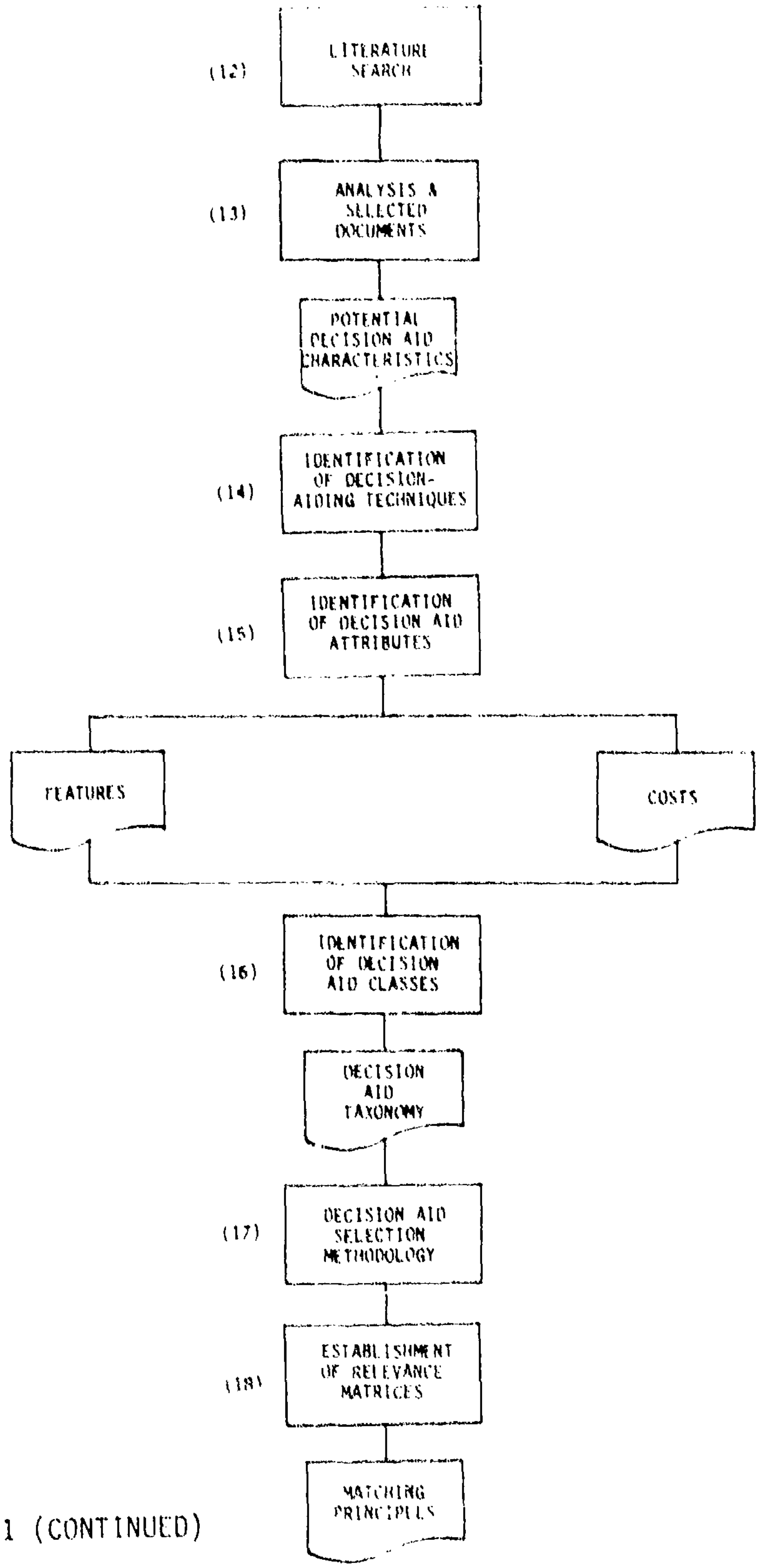


FIGURE 1-1 (CONTINUED)

(3) The available documentation was reviewed. It included doctrinal publications and documents related to the development of the MTACCS.

(4) The selected documents were then analyzed in order to identify the decision tasks within the MAB environment. The outcome of this analysis was a workable list of decision tasks. In addition, as a by-product, a set of facts bearing on the selection/design of decision aids for the MAB environment was obtained.

(5) The identified decision tasks were then analyzed in terms of their information requirements, relevant attributes, and functional requirements.

(6) Based on the above analysis, classes of decision tasks with common required decision-making functions and attributes were identified and decision tasks were classified, yielding a workable decision task taxonomy oriented toward identification of relevant decision aids.

(7) In order to develop a meaningful set of decision-maker attributes, a sur[illegible] the pertinent literature was conducted and a nur[illegible] of relevant technical papers selected.

(8) The analysis of the selected documents resulted in the construction of a partial set of decision-maker attributes.

(9) A preliminary interview of Marine Corps experts conducted at MCTSSA provided additional inputs which, together with the partial set previously obtained, yielded a preliminary set of decision-maker attributes.

(10) An expert interview was then conducted to refine and finalize this preliminary set.

(11) The relations existing among decision maker attributes, together with the plausible classes of decision makers were identified, thus yielding the decision maker taxonomy. The general conclusion, however, was that decision makers do not relate in a quantifiable manner to decision tasks in the MAB decision-making environment.

(12) For the decision aid taxonomy phase, a literature search resulted in the selection of a number of relevant documents.

(13) The selected documents were analyzed, which yielded a preliminary set of potential decision-aid characteristics.

2. THE MARINE AMPHIBIOUS BRIGADE DECISION-MAKING ENVIRONMENT

2.1 Introduction

As a first step toward the construction of a MAB decision task taxonomy, Marine Corps doctrinal publications were analyzed in three steps documented in the next three sections. First, it was sought to acquire a better understanding of the environment under study itself. In other words, What is a MAB? What is a MAB operation? How do people relate to each other in a MAB operation? What do they do? etc.. The results of this phase are documented in Section 2.2.

The next logical step, documented in Section 2.3, was the identification of the decision tasks pertaining to the MAB environment. Using an already available methodology, relevant documents were analyzed, thus leading to a list of MAB decision tasks which were later the subject of an analysis leading to the decision task taxonomy. Finally, as a by-product of the analysis of Marine Corps doctrinal publications, a set of facts relevant to decision-aiding design and selection strategies was identified. They are documented in Section 2.4.

2.2 The MAB Environment

2.2.1 Marine Amphibious Brigade. Three types of Marine air-ground task forces (MAGTF) can be assembled when an operation involving amphibious assault is contemplated:

(1) Marine Amphibious Force (MAF).
(2) Marine Amphibious Brigade (MAB).
(3) Marine Amphibious Unit (MAU).

The MAF is the largest of the Marine air-ground task force. It is capable of conducting large scale operations, including sustained operations ashore. The MAU is the smallest force organization. It is generally used in operations of very limited scope and is normally supported from its seabase. The MAB is the most flexible task force organization. Although used to carry out missions of limited scope, it is capable of conducting amphibious assaults in low and mid-intensity conflicts. It can be deployed forward afloat for extended periods and provide quasi-instantaneous reponses in potential crisis situations. The MAB has been selected for analysis since it provides a test bed where enough information is handled to render studies meaningful without becoming unmanageable.

All Marine air-ground task forces are designed to accommodate integration of air and ground operations. They are organized, as depicted in Figure 2-1, in four major elements:

(1) Command element.
(2) Ground combat element.
(3) Aviation combat element.
(4) Combat service support element.

In MAB, the ground combat element, although tailored to accomplish the particular mission, is typically equivalent to a Regimental Landing Team (RLT), while the aviation combat element is generally anMarine Aircraft Group (MAG). In particular, it has the required anti-air warfare capabilities and is equipped to establish itself ashore early, in pre-existing or expeditionary airfields.

The command relationship between Navy and Marine Corps forces during the planning phase is depicted in Figure 2-2. During this phase matters upon which the Amphibious Task Force Commander (CATF) and the

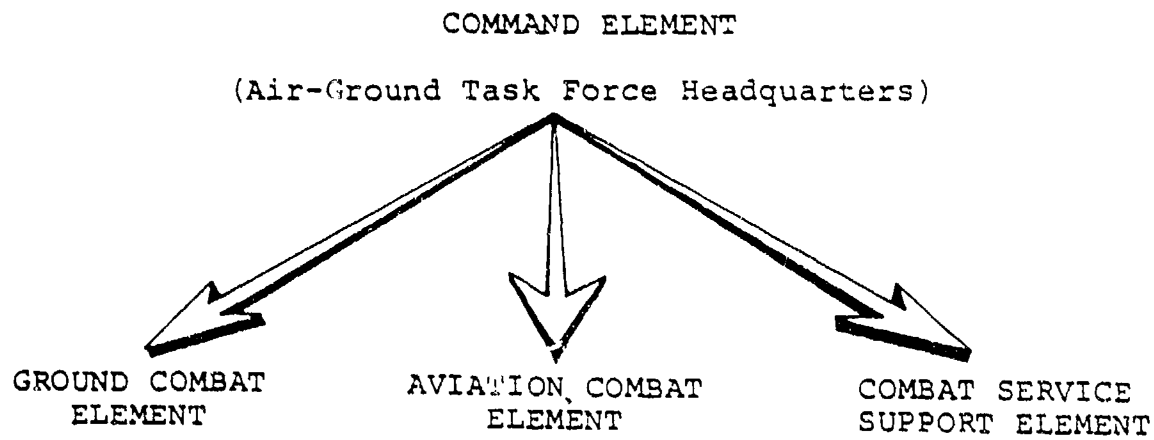


FIGURE 2-1.
COMPONENTS OF THE AIR-GROUND
TASK FORCE (FROM FMFM 5-1 p.37)

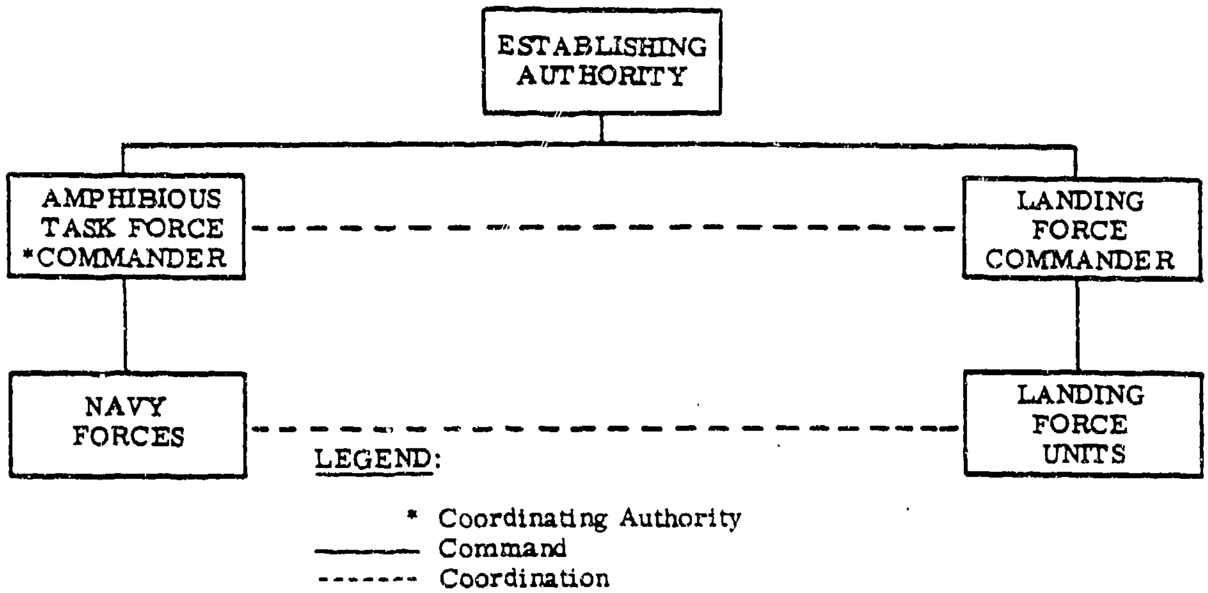


FIGURE 2-2.
COMMAND RELATIONSHIPS OF AN AMPHIBIOUS TASK FORCE
DURING THE PLANNING PHASE (FROM FMFM 3-1 p.76)

Landing Force Commander (CLF) cannot reach an agreement are referred to their common superior. Upon commencement of the amphibious operation, however, the CATF assumes full responsibility over the force.

2.2.2 Amphibious Operation. "An amphibious operation is an attack launched from the sea by naval and landing forces embarked in ships or craft involving a landing on a hostile shore" (FMFM 3-1). Complete within itself, the amphibious operation integrates ground, air, and naval forces in a concerted effort to accomplish the mission assigned by higher headquarters. The closest cooperation and most detailed coordination among all participating forces are required for the success of the amphibious operation during which the landing force has to build up full combat strength from zero-base in a few days. Consequently, an important feature of amphibious operations is the absolute necessity of correctly integrating and coordinating all efforts within task force components which are diverse in nature and composition.

Starting with the receipt of the Initiating Directive and terminating upon completion of the mission, the amphibious operation includes the following phases:

(1) Embarkation.
(2) Rehersal.
(3) Movement to the objective area.
(4) Preparation of the objective area.
(5) Assault.
(6) Operations ashore.

Each phase has to be carefully planned and executed according to closely monitored conditions.

2.2.3 Staff Organization and Techniques. As described in Figure 2-3, the structure of Marine Corps organizations includes a commander responsible for the actions of his units, an assistant, subordinate unit commanders, and general and special staffs. General staffs are composed of officers assisting and advising the commander. They are organized into these functional areas:

(1) Personnel.
(2) Intelligence.
(3) Operations.
(4) Logistics.
(5) Civil Affairs.
(6) Financial Management.

Common to all staff officers are the following:

(1) Provide information and advice.
(2) Make estimates.
(3) Make recommendations.
(4) Prepare plans and orders.
(5) Advise other officers of the commander's plans and policies.
(6) Supervise execution of plans and orders.

On request, special staff perform unique duties they have been trained for. Within the framework of their area of specialization, they advise, plan, supervise, and coordinate operations. Examples of special staff officers are: (1) automated data processing systems engineer, (2) amphibious tractor officers, and (3) anti-mechanized officer.

The commander directs and controls the operations. The two basic processes involved are:

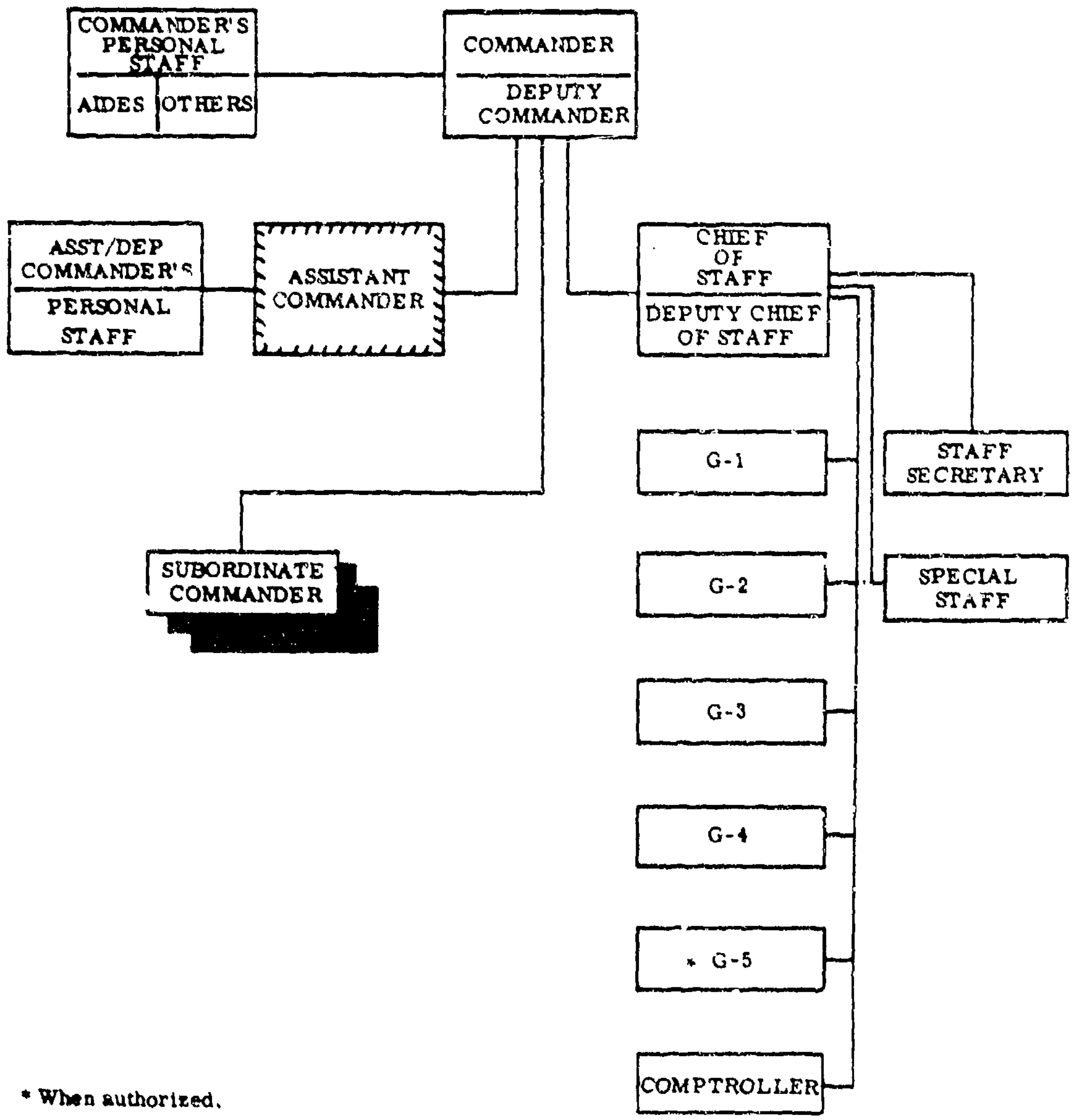


FIGURE 2-3.
MARINE CORPS STAFF
ORGANIZATION (FROM FMFM 3-1 p.3)

(1) Planning, divided into preliminary planning during which the commander assesses what to do and detailed planning, during which how to do it is determined.
(2) Supervision to ensure mission completion.

The sequence of actions in making and executing decisions described in Figure 2-4 is basically the same at all echelons of command, although level of complexity and time pressure may vary.

2.2.4 Doctrinal Publications. The doctrine governing the conduct of Marine Corps operations is set forth in two types of publications:

(1) Landing Force Manuals (LFM's), which are basic doctrinal publications expressing the doctrine to be employed in amphibious operations.
(2) Fleet Marine Force Manuals (FMFM's) which are "user type" publications and comprehensively describe the tactics, techniques and procedures to be used in landing force operations.

Doctrinal publications are reviewed every two years to take into account the experience gained in exercises. The existing Marine Corps doctrinal publications are listed in Table 2-1.

The present tactical command and control system is mainly described in FMFM 3-1, which is an account of the procedures and techniques to be used for planning and conducting tactical operations, and in the FMFM's of the 6 series, which provide guidance for commanders of Marine Division and subordinate echelons. The consensus is that, tested in battle and exercises, this system indeed works. Although it was felt by interviewed Marine Corps personnel that the logical steps of decision-making as they are described in doctrinal publications are sometimes too formal, it was obvious to them that the doctrine provided a very good framework for this study.

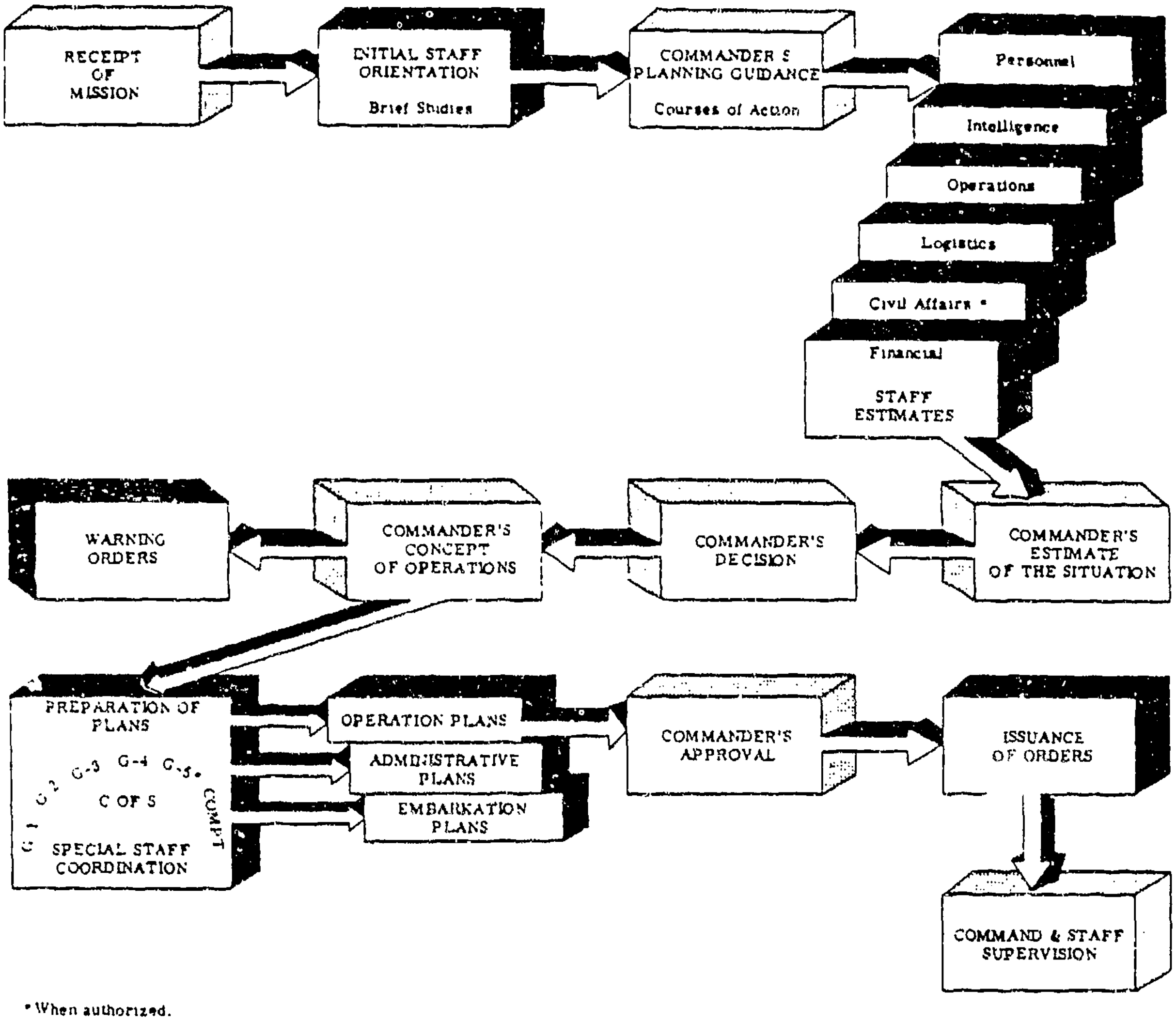


FIGURE 2-4.
SEQUENCE OF COMMAND
AND STAFF ACTION (FROM FMFM 3-1 p.40)

TABLE 2-1

MARINE CORPS DOCTRINAL PUBLICATIONS

Landing Force Manuals

LFM 01, Doctrine for Amphibious Operations

LFM 02, Doctrine for Landing Forces

LFM 03, Armed Forces Doctrine for Chemical and Biological Weapons Employment and Defense

Fleet Marine Force Manuals

FMFM 0-0, Doctrinal Publications Guide

FMFM 1-2, Marine Troop Leaders Guide

FMFM 1-3, Basic Rifle Marksmanship

FMFM 1-3A, Field Firing Techniques

FMFM 1-3B, Sniping

FMFM 2-1, Intelligence

FMFM 2-2, Amphibious Reconnaissance

FMFM 2-3, Signal Intelligence/Electronic Warfare Operations (U)

FMFM 3-1, Command Staff Action

FMFM 3-2, Amphibious Training

FMFM 3-3, Helicopterborne Operations

FMFM 4-1, Logistics and Personnel Support

FMFM 4-2, Amphibious Embarkation

FMFM 4-3, Shore Party and Helicopter Support Team Operations

FMFM 4-4, Engineer Operations

FMFM 4-5, Medical and Dental Support

FMFM 4-6, Air Movement of Fleet Marine Force Units

FMFM 4-7C, Effectiveness Data for Mortar

TABLE 2-1 (CONTINUED)

FMFM 4-7D-1, Effectiveness Data for Howitzer

FMFM 4-7D-2, Effectiveness Data for Howitzer

FMFM 4-7D-3, Effectiveness Data for Howitzer

FMFM 4-7D-4, Effectiveness Data for Gun

FMFM 4-7D-5, Effectiveness Data for Mortar

FMFM 4-7D-6, Effectiveness Data for Rocket

FMFM 4-7E-1, Effectiveness Data for the 5-Inch/38 Naval Twin Gun Mount Mks 28, 32, and 38 with Gun Fire Control System Mk 37 (U).--(C)

FMFM 4-7E-2, Effectiveness Data for 5-Inch/54 Naval Single-Gun Mount Mk 42 with Fire Control System Mk 68 (U).--(C)

FMFM 4-7F-1, Effectiveness Data for Tank, Combat, Full Tracked: 105mm Gun, M60A1 (U).--(C)

FMFM 4-7G-1, Weapons/Ammunitions Characteristics (U)

FMFM 4-7H-2, Lethal Areas of Selected U.S. Army, U.S. Navy, and U.S. Marine Corps Surface-to-Surface Weapons Against Personnel and Material Targets (U)

FMFM 4-7H-3, JMEN/SS Manual of Fragmentation Data (U)

FMFM 4-8, Handling of Deceased Personnel in Theaters of Operations

FMFM 5-1, Marine Aviation

FMFM 5-2, Weapon Effectiveness, Selection, and Requirements--Basic JMEN/AS (U)

FMFM 5-2F Series, Joint Munitions Effectiveness Manuals (U)

FMFM 5-2G, Weapon Characteristics Handbook (U)

FMFM 5-2H, Target Vulnerability (JMEM) (U)

FMFM 5-2I, Delivery Accuracy (U)

FMFM 5-3, Assault Support

FMFM 5-4, Offensive Air Support

TABLE 2-1 (CONTINUED)

FMFM 5-5, Antiair Warfare
FMFM 5-5A, Antiair Warfare Supplement
FMFM 5-5B, Employment of Light Antiaircraft Missile Battalion
FMFM 5-5C, Employment of Forward Area Air Defense Battery
FMFM 5-6, Air Reconnaissance
FMFM 6-1, Marine Division
FMFM 6-2, Marine Infantry Regiment
FMFM 6-3, Marine Infantry Battalion
FMFM 6-4, Marine Rifle Company/Platoon
FMFM 6-5, Marine Rifle Squad
FMFM 7-1, Fire Support Coordination
FMFM 7-2, Naval Gunfire Support
FMFM 7-4, Field Artillery Support
FMFM 7-5, Antiair Warfare Operations
FMFM 7-6, Employment of Light Antiaircraft Missile Battalion
FMFM 8-1, Special Operations
FMFM 8-2, Counterinsurgency Operations
FMFM 8-3, Advanced Naval Base Defense
FMFM 8-4, Doctrine for Navy/Marine Corps Joint Riverine Operations
FMFM 8-4A, Operations in Riverine Areas
FMFM 8-6, Joint Manual for Civil Affairs
FMFM 9-1, Tank Employment/Antimechanized Operations
FMFM 9-2, Amphibious Vehicles
FMFM 10-1, Communications
FMFM 11-1, Nuclear, Chemical, and Defensive Biological Operations in the FMF
FMFM 11-3, Employment of Chemical Agents
FMFM 11-3B, Employment of Chemical Agents

TABLE 2-1 (CONTINUED)

FMFM 11-4, Staff Officers' Field Manual: Nuclear Weapons Employment Doctrine and Procedures

FMFM 11-4A, Staff Officers' Field Manual: Nuclear Weapons Employment Effects Data (U)

FMFM 11-4B, Staff Officers' Field Manual: Nuclear Weapons Employment Effects Data

FMFM 11-5, Operational Aspects of Radiological Defense

2.2.5 The MTACC Systems. The modern battlefield (typically in the post-1980 time frame), which can be expected to be the theater of landing force operations, will be that of a very high fire power characterized by sophisticated weaponry and highly mobile enemy forces. Enemy electronic warfare and a rapidly changing situation will create what is termed a "fog of battle," confusing for the tactical commander who has to keep control of his forces while buried in a flow of raw data.

It became clear during recent MAB exercises, that although the tactical C2 system outlined in doctrinal publications fulfills its functions, it does it too slowly for the type of environment described above (see TCO Maneuver Control - Concept Paper, Fourth Draft, MCTSSA, unpublished manuscript). To keep up with a rapidly changing situation, the Marine Corps has defined a conceptual association of command and control systems, the Marine Tactical Command and Control Systems (MTACCS), consisting of eight interacting, functionally-oriented systems using the same design philosophy. These systems are:

(1) Marine Integrated Fire and Air Support System (MIFASS).
(2) Tactical Combat Operations System (TCO).
(3) Marine Air Command and Control System - 1985 (MACCS-85).
(4) Marine Air-Ground Intelligence System (MAGIS).
(5) Position Location Reporting System (PLRS).
(6) Marine Integrated Personnel System (MIPS).
(7) Marine Integrated Logistics System (MILOGS).
(8) Tactical Warfare Simulation Evaluation and Analysis System (TWSEAS).
(9) Landing Force Integrated Communications System (LFICS).

The MTACCS will provide tactical commanders with timely and accurate information, together with ability to plan changes and rapidly pass orders to their subordinates. They should remedy the deficiencies of the present

C2 system without changing its characteristics, insofar as the decision-making process and hence this study, are concerned.

The existence of a research and development organization such as MCTSSA and the fact that the on-going effort aimed at developing and eventually fielding the TCO system led to the actual construction of a test bed, afford a unique opportunity to test the validity and usefulness of the aids to be developed in this project.

2.3 Decision Task Identification

2.3.1 Organization. Since the present taxonomy of decision tasks is aimed at decision-making requirements, the top-level organization must be chosen so as to incorporate natural "clusters" emerging from the classification process. The MAB decision-making environment should actually be broken down to functions which are natural from a decision-analytic standpoint and a military standpoint as well. The following functions satisfy these requirements:

(1) Operations.
(2) Intelligence.
(3) Fire and Air Support.
(4) Personnel and Logistics.

The area of operations is subdivided into (1) planning and (2) control. Planning tactical operations is itself divided into: (1) preliminary planning and (2) detailed planning. While in the preliminary planning phase, the commander is concerned with determining what to do. In the detailed planning, he seeks the optimum way of implementing his preliminary planning decision. In controlling tactical operations, the commander monitors the situation and sees that the operations evolve satisfactorily, questioning at all times his need for action.

The area of intelligence is concerned mainly with the handling of information; and consequently, the decision-making process is clearly different from the one described in the area of operations.

In the areas of fire and air support, and personnel and logistics, (after providing a preliminary estimate of supportability serving as a basis for the preliminary planning decision of higher echelon commanders) the commander or staff officers concern themselves with planning for support of the announced higher echelon decision. After determining the overall support requirements, the commander allocates means. The detailed requirements are then defined and the plans are promulgated. Support operations, according to these plans, are closely monitored to determine if action is necessary. Although fire and air support on one hand, logistics and personnel on the other, involve processes fairly similar in nature, they have been distinguished as two different areas since they satisfy two radically different types of needs. Furthermore, since the taxonomy is to be used by military experts rather than decision analysts, the subdivisions must be meaningful from a military standpoint.

2.3.2 <u>Decision-Task Identification Methodology.</u> In this section, a methodology for identification of decision tasks in a decision/non-decision environment is described. This methodology, developed by Saleh et al. in "Analysis of Requirements and Methodology for Decision Training in Operational Systems," Final Report, NTEC, Feb. 1978, is based on the definition of a decision task, specifying the characteristics of a "filter" which passes all decision tasks and only decision tasks. As later assessed during interviews of Marine Corps personnel, this methodology, after proper supplementary explanations, is accessible to people who are not decision analysts. The characteristics of the above mentioned "filter" are the following:

(1) The objective of a decision task is to select an alternative from a specified set of alternatives.

(2) This selection may require the formulation of alternatives (problem structuring).

(3) There is a lack of completely specified criteria for either alternative formulation or alternative selection.

Although (2) is not binding (1) and (3) must both be realized for a task to qualify as a decision task.

2.3.3 Decision-Task Identification. The method of approach consisted of two phases:

(1) Identification of decision-tasks from doctrinal publications by Perceptronics.

(2) Verification (additions/deletions) by interviews of knowledgeable Marine Corps personnel.

For the first phase, documents had to be carefully selected because the number of doctrinal publications is very large (see Table 2-1) and analyzing all of them was clearly beyond the scope of the present study. Consequently, for each of the four functions above mentioned, specific documents were suggested by MCTSSA personnel as follows:

Operations	FMFM 3-1, 6-1, 6-2, 6-3
Intelligence	FMFM 2-1
Fire and Air Support	FMFM 7-1, 5-1, 7-2, 7-4
Logistics and Personnel Support	FMFM 4-1

In addition, for the areas of Operations and Intelligence, the document Draft Report - "TCO Functional Analysis and TCO Information Flow Analysis," Dec. 1977 (prepared by the Computer Science Corporation in support of MCTSSA effort for the TCO Detailed Requirement Document) was used to organize the matter in tasks and subtasks. MCTSSA's MIFASS Detailed

Requirement Document Vol. 2.21 Mar. 1977, similar in nature to the previous document, was used in the area of Fire and Air Support. In addition, FMFM 0-0 was used as a guideline for all functions, but the conclusions were drawn from other publications since FMFM 0-0 has not yet been approved by Marine Corps Headquarters and is consequently not a quotable source.

Using the decision-task identification methodology described previously in Section 2.3.2, the list of decision tasks encountered within the MAB decision-making environment was established. Each decision task was identified with a decision-making keyword. Whenever possible, tasks have been renamed using a decision-making verb. For instance "Selection of landing areas" has been relabeled "Select landing areas." However, in many cases decision tasks were described in a way which does not enhance their decision-related nature. For instance, in the task labeled "Prepare planning guidance," encountered in the preliminary planning of operations phase, the decision-making keyword is "guide" and not prepare. A label for this task, reflecting its decision nature, would be "Guide Planning." However, since "Planning Guidance" appears in doctrinal documents, the task name was not changed even though it is identified with the decision keywork "guide." The hierarchical list of decision tasks encountered can be found in Table 2-2. A list of the decision-making keywords encountered during the decision task identification phase can be found in Table 2-3. These keywords could serve as a basis to rationalize the use of decision-making terms so that decision making keywords would be used in decision-making contexts only.

During the second phase, Marine Corps personnel with field and exercise experience in the areas of operations, intelligence, fire support, air support, logistics and personnel support were interviewed for the purpose of gathering information about the nature and characteristics of decision tasks within the MAB environment. As a first step toward this goal, acceptance or rejection of the list of decision tasks identified by Perceptronics was sought. After giving the definition of a decision

TABLE 2-2

LIST OF MAB DECISION TASKS

1. OPERATIONS

1.1 PRELIMINARY PLANNING

1.1.1 ATF/LF Preliminary planning

- Determine ATF Objectives
- Select ATF General C/A
- Determine LF Mission
- Select Beachhead
- Select Landing Areas
  - Designate Landing AReas
  - Select Primary and Alternative Landing Areas
- Determine Tentative D-Day and H-Hour
- Formulate LF Concept of Operations Ashore
- Decide on Other Major Issues

1.1.2 Develop Operations Estimate

- Analyze Landing Force Mission
- Generate Friendly Courses of Action
- Analyze Friendly Courses of Action
  - Analyze Characteristics of the Area of Operations
  - Analyze Relative Combat Power
- Analyze Enemy Courses of Action
- Compare Friendly Courses of Action
- Select Course of Action for Commander's Briefing

TABLE 2-2 (CONTINUED)

1.2 DETAILED PLANNING

1.2.1 Prepare Outline Plan

Determine Task Organization and Troop List

Determine Missions for Subordinate Units

Determine Tactical Control Measures

Select Landing Beaches and Landing Zones

Select Date and Time for Landing(s)

Select Formation for Landing

Select Shipping Allocation

Outline Alternative Plans

1.2.2 Prepare Plan of Attack

Prepare the scheme of Maneuver

Finalize Objectives for all Units

Finalize Distribution of Forces

Determine Control Measures

Prepare Landing Plan

Determine Lift Requirements

Allocate Landing Means

Determine Landing Sequence

Determine Assault Sequence

1.3 CONTROL TACTICAL OPERATIONS

1.3.1 Control Ground Operations

Analyze Tactical Situation

Analyze Available Resources

Appraise Need for Action

Appraise Need for Information

TABLE 2-2 (CONTINUED)

1.3.2 Integrate Fire and Maneuver

Correlate Current Status and Mission Requirements

Evaluate Rate and Direction of Planned and In-Progress Fires

Update Control Measures

1.3.3 Modify the Scheme of Maneuver

Evaluate Rate and Direction of Present Scheme of Maneuver

Update Scheme of Maneuver

2. INTELLIGENCE

2.1 DEVELOP THE INTELLIGENCE ESTIMATE

2.1.1 Coordinate Report

Identify Characteristics of the Area of Operations

Determine Enemy Military Situation

Analyze Enemy Unconventional and Psychological Warfare Situation

Analyze Enemy Intelligence and Counter-Intelligence Activities

2.1.2 Determine All Enemy Capabilities

Identify all Enemy Capabilities

Select Enemy Capabilities Suitable for Further Analysis

Assess Earliest Time of Execution of Each Enemy Capability

Identify Maximum Strength of Each Enemy Capability

TABLE 2-2 (CONTINUED)

2.1.3 Analyze Enemy Capabilities

Determine Impact on Mission of Each Enemy Capability

Predict Relative Probability of Adoption of Each Enemy Capability

Identify the Vulnerabilities of the Enemy

2.2 DEVELOP THE COLLECTION PLAN

Determine Basic Requirements

Determine EEI's

Select Collection Agencies

Supervise and Coordinate Collection Effort

Appraise Need for Revision of the Collection Plan

2.3 DEVELOP THE RECONNAISSANCE AND SURVEILLANCE PLAN

Determine Requirements for R&S

Integrate Reconnaissance and Surveillance

Coordinate R&S Planning with Other Operations

2.4 PERFORM TARGET INTELLIGENCE

Develop Target Acquisition Plan

Interpret Target Information

3. FIRE AND AIR SUPPORT

3.1 PREPARE INITIAL ESTIMATES

Prepare Naval Gunfire Estimate

TABLE 2-2 (CONTINUED)

Prepare Aviation Estimate
Prepare Artillery Estimate

3.2 PLANNING

3.2.1 Determine Overall LF Fire Support Requirements
    Formulate Preliminary NGF Plan
    Formulate Preliminary Aviation Plan
    Formulate Preliminary Artillery Plan

3.2.2 Concolidate Fire Support and Naval Requirements

3.2.3 Compare Overall Requirements to Means

3.2.4 Adjust Preliminary Fire Support Plans

3.2.5 Determine Detailed Requirements
    Determine Detailed NGF Support Requirements
        Analyze Targets
        Compute Ammunitions
        Compute Duration of Pre-D-Day Bombardment
        Compute Ship and Aircraft Requirements
        Determine Zones of Fire
        Estimate Post-D-Day Daily Requirements
    Determine Detailed Air Support Requirements
        Analysze Targets and Mission
        Determine Amount of Aviation Required
        Determine Ammunition, Bombs, and Rockets
        Determine Supply and Resupply Requirements

TABLE 2-2 (CONTINUED)

Determine Detailed Artillery Requirements
- Analyze Mission, Scheme of Maneuver, and Enemy Forces
- Determine Artillery Required
- Compute Ammunition
- Estimate Resupply
- Analyze Effect of NGF and Air Support on Artillery Requirements

3.2.6 Coordinate Determination of Requirements
- Determine Target Classification and Priority
- Select Most Effective Means of Attacking Targets
- Determine Method and Sequence of Attack of Targets

3.2.7 Develop Coordination Measures
- Define Zones of Fire
- Define Boundaries
- Define Coordinated Fire Line
- Define Fire Support Coordination Line
- Define Restrictive Fire Lines
- Determine Airspace Coordination Area
- Define Trajectory Limitiations
- Define Free-Fire Area
- Define No-Fire Area
- Define Restrictive Fire Area

3.2.8 Develop Plans for Fire and Air Support
- Develop NGF Plan
- Develop Air Support Plan

TABLE 2-2 (CONTINUED)

Develop Artillery Plan
Resolve Conflicts and Adjust Plans
Develop Fire Support Coordination Tab

3.3 CONTROL

Coordinate Planned Fires with Ongoing Troop Movements
Resolve Conflicts Between Schedules Fires and Tactical Operations
Monitor Requests for Fire Support
Coordinate Targets of Opportunity and Supporting Arms
Determine the Effect of Fire
Update Control Measures for Friendly Fires

4. LOGISTICS AND PERSONNEL SUPPORT

4.1 ESTIMATES OF SUPPORTABILITY

Develop Logistics Estimate
Develop Personnel Estimate
Assess Personnel Situation
Compare C/A's From a Personnel Standpoint

4.2 PLANNING

4.2.1 Finalize Concept of Logistic Support
Determine Supply and Resupply Requirements
Determine Transportation Requirements
Make Loss Estimate

TABLE 2-2 (CONTINUED)

Determine Medical Requirements
Determine Service Requirements

4.2.2 Allocate Means
Allocate Means to Subordinate Echelons
Assign Logistic Support Responsibilities

4.2.3 Compute Detailed Requirements
Assess Personnel Situation
Compare Courses of Action From a Personnel Standpoint

4.2.4 Update Plans According to Results of Rehearsals

4.3 CONTROL

Monitor Landing Progress
Monitor Unloading Period
Coordinate Flow of Men, Material, and Equipment
Monitor Level of Supplies for Combat Units
Monitor Channels of Supply, Service, and Communication

TABLE 2-3

MAB DECISION-MAKING KEYWORDS

ANALYZE	FORMULATE
ALLOCATE	IDENTIFY
APPRAISE	INTERPRET
ASSESS	INTEGRATE
ASSIGN *	MODIFY
COMPARE	MONITOR *
COMPUTE *	OUTLINE *
CONSOLIDATE	PERFORM *
CONTROL	PHASE
CORRELATE	PLAN
DECIDE	PREDICT
DEFINE	PREPARE
DESIGNATE *	RESOLVE
DETERMINE	SCHEDULE
ESTIMATE	SELECT
EVALUATE	SUPERVISE
FINALIZE	UPDATE

* Non decision-making keywords
used in a decision-making context

task used in the decision task identification methodology, the Marine Corps personnel interviewed were asked to examine the list of the decision tasks and to suggest the necessary amendments (deletions or additions). In the area of Fire and Air Support, however, it was suggested to reorganize the task/subtask structure to render it more natural from a military standpoint. The specific suggestions were taken into account and Table 2-2 depicts the modified list. A sample of the questionnaire used for the interviews is given in Table 2-4 (only part I is relevant to the decision-task identification phase). During the interviews, interviewees showed interest in the way the tasks were labeled and understood the possible usefulness of using decision-task keywords to label decision tasks.

2.4 Insights and Findings

In this section, facts and conclusions drawn as a by-product of the in-depth analysis of doctrinal publications are highlighted. They were confirmed during interviews of Marine Corps personnel who pointed out key characteristics of the MAB decision-making environment. Many of these insights and findings will appear in the next chapter of the report and are amplified here. Although many other factors may enter in consideration, designers of decision-aids adapted to the Marine Amphibious Brigade decision-making environment should find these facts useful.

The Doctrine Does Not Provide Formal Rules to Perform Trade-Off Analyses. In performing supportability estimates, staff members analyze the friendly courses of action under formal consideration and appraise their respective advantages and disadvantages from their particular standpoint (aviation, logistics). Then, taking into consideration these advantages and disadvantages, they rank the alternatives explaining the reasons behind their choice. If a course of action is grossly disadvantageous, the reason is obvious for ranking it last; but when a possible trade-off exists, no formal rules to carry out the analysis are available. A

TABLE 2-4

SAMPLE QUESTIONNAIRE
QUESTIONNAIRE

NAME:____

GRADE:____

SPECIALIZATION:____

HOW LONG IN SERVICE?____

HOW LONG IN OPERATIONS?____

DID YOU PARTICIPATE IN MAB EXERCISES?______________________________

WHEN AND IN WHAT CAPACITY?____

HOW LONG AT MCTSSA?____

WHICH OF THE MTACC SYSTEMS DID YOU SPECIALIZE IN?___________________

TABLE 2-4 (CONTINUED)

PART I - DECISION TASK IDENTIFICATION

A decision task is defined by the conjunction of three following characteristics:

(1) The objective of a decision task is to select an alternative from a specified set of alternatives.
(2) This selection may require the formulation of alternatives (problem structuring).
(3) There is a lack of completely specified criteria for either alternative formulation or alternative selection.

Using the above definition and your background knowledge, go through the lists of tasks given to you and confirm or deny their decision-task nature. Can you think of any important deletion or addition? (Focus mainly on your area of specialization.)

____

____

____

PART II - DECISION TASK CLASSIFICATION

During this phase, we would like you to choose one decision task, in your area of specialization, that you consider important and describe what its characteristics are. The dimensions used will be the following:

1. Information requirements (or inputs).
2. Characteristics.

(1) Single attribute - multi attribute.
Is the decision made on the basis of one or more value dimensions?

TABLE 2-4 (CONTINUED)

(2) Individual - group.
Is the decision made by a single individual or a group of people?

(3) Static - dynamic.
Does the action produce consequences that may vary with time?

(4) One shot - repetitive.
Is the decision made once or repetitively?

(5) Certainty - risk.
Are the consequences of each action predictable with certainty or not?

(6) Abstract - concrete.
Is the decision problem posed in general or task-specific terms?

(7) Well-defined - ambiguous.
Is the set of alternatives, states of nature and outcomes completely describable, well-defined and well-understood for this decision situation?

(8) Decision making - decision execution.
Are there decision solutions available to solve the decision problem, i.e., does the decision task consist only of a recognition of current environmental conditions?

(9) Time critical - time relaxed.
Is the decision maker under time pressure to make his decision?

(10) Small probability high loss - normal ranges.
Are the ranges for probabilities and losses normal or unusual?

(11) Type 1 (problem structuring), Type 2 (alternative selection), or Type 3 (problem structuring and alternative selection).
"Problem structuring" includes formulation of alternatives and establishment of outcomes while "alternative selection" consists

TABLE 2-4 (CONTINUED)

of assessing utilities and probabilities, applying decision rules or selecting the best alternative.

For the task you have chosen, write below:

1. Information Requirements

____

____

____

2. Characteristics

(1) ____

(2) ____

(3) ____

(4) ____

(5) ____

(6) ____

(7) ____

(8) ____

(9) ____

(10) ____

(11) ____

We now would like to find out the characteristics of a decision task that we have chosen in your area of specialization.

TABLE 2-4 (CONTINUED)

If your area of specialization:	Concentrate on:
Operation	Select Landing Areas
Intelligence	Predict Relative Probability of Adoption of Enemy Capabilities
Fire & Air Support	Estimate NGF supportability of C/A
Logistics & Personnel	Compute overall supply support requirements

For the task you concentrated on, perform the same analysis as before:

1. Information Requirements

 ____

 ____

 ____

2. Characteristics

 (1) ______________________________

 (2) ______________________________

 (3) ______________________________

 (4) ______________________________

 (5) ______________________________

 (6) ______________________________

 (7) ______________________________

 (8) ______________________________

 (9) ______________________________

 (10) ______________________________

 (11) ______________________________

TABLE 2-4 (CONTINUED)

Can you suggest any other attributes to characterize decision tasks?

value judgment is performed, however, and since the commander might not have the same value system as his staff members, the reasons behind the staff's choice have to be explicitly defined. For example, assume that two courses of action (C/A) are under formal consideration. Assume that one of them requires more aviation support, but provides for possible seizure of certain enemy installations earlier than the other. The tactical air commander might prefer a C/A requiring less aviation support but the Amphibious Task Force Commander, who has a broader view of the operation, might know that timeliness is more important in the particular instance and consequently disregard his staff officer's recommendation. If the reasons behind the staff officer's choice were not spelled out, it would not be possible for the commander to integrate the estimate into a broader picture.

Except For Assessment Of Weapon Effectiveness, The Doctrine Does Not Formally Call for Probability Estimates. All estimates are summarized in the form of a ranking of courses of action accompanied by a statement of the reasons leading to that ranking. In spite of a misleading title ("Determination of Relative Probability of Adoption," FMFM 2-1, Par. 908, g.), the intelligence estimate is no exception; the G2 is only required to list the possible enemy responses in order of decreasing probability and substantiate his conclusions. The fact that only a ranking of the alternatives is available, as opposed to a complete knowledge of the probabilities, imposes restrictions on the type of aid which would be acceptable to the user in performing his tasks.

Probabilistic Statements Are Generally Treated As Deterministic. When a tactical commander wants to inquire about a viable enemy course of action (e.g., attack), he generally does not ask "What is the probability that the enemy will attack?" He most frequently asks "Tell me if the enemy will attack." The G2 then answers using indicators to substantiate the statement. This practice of substituting probabilistic statements with deterministic statements is prevalent at lower echelons, but no viable enemy course of action is deliberately omitted, even the less likely ones. In view of these indicators, a course of action will be considered. As new indicators are received, new candidate courses of action may be considered. In light of the doctrine of enemy capabilities, considering all possible enemy capabilities is very important, while ordering them is less important. However, in times of scarce resources, commanders cannot afford the luxury of devising strategies against all possible actions and must make some likelihood judgment on the enemy's response.

The Enemy Is Always Given The Benefit Of The Doubt. In the doctrine of the Estimate of the Situation, the commander must match each of his viable courses of action with each of the enemy's possible courses of action and decide on the best alternative. In doing so, it is assumed that the enemy can always execute his actions in the best possible manner resulting in the highest damage for the friendly forces. Furthermore, it should be noted that the U.S. doctrine, in general, is a doctrine of enemy capabilities versus enemy intentions. In other words, the major factor to consider is what the enemy can do (i.e., when the enemy has a capability, he will make the best use of it) versus what the enemy intends to do. This implies that doctrinal solutions will always use criteria of the minimax type, thus providing insurance against the worst possible outcome. This point is very well illustrated in Haywood, 1954.

The Guidelines Used For Assessing Information Reliability Are Not precise. The rating system used for evaluating information elements consists of two components: (1) source reliability and (2) accuracy. The reliability of the source is rated with a letter from A (completely reliable) to F (reliability cannot be judged) while the accuracy is measured by a number from 1 (confirmed by other sources) to 6 (truth cannot be judged). These class labels are not precise in the sense that there is, for example, no clear distinction between "fairly reliable" and "not usually reliable." Although reliability and accuracy are distinct features, they are sometimes confused. In addition, the same letter or number does not have the same meaning for every user, thus resulting in a "communication gap" between users. Experimental results substantiating these statements can be found in Samet, 1976.

Communication Is Always The Major Problem. In MAB post-exercise reports, as in actual operations, the communications problem is a *leitmotiv*. It is not usually a hardware problem (malfunction of equipment), but rather, a human problem as the communication equipment is overused and misused, resulting in enormous overloads and backlogs. Lower echelons rarely provide required information in a timely manner, nor do they receive FRAG orders in time. Thus, the control of tactical operations is dangerously hampered. Tactical commanders feel that if this problem could be solved, they would make better decisions.

"Life Is Easy At Battalion Level, But At Division Level The Tactical Commander Is A Business Executive." This concept reflects a consensus among Marine Corps personnel experienced in operations that the "complexity" of the decision-making process increases at higher echelons. Although less time is available for decision making at lower echelons, it is actually easier to come up with a best course of action as the set of alternatives is smaller and the commander, closer to the field, has a better understanding of his environment. At higher echelons, there is an information overload and the commander, even though surrounded by his staff who advises him, has too many decisions to make. To solve this problem, the commander leaves specific decisions, such as resource allocation, to lower echelon commanders.

Some Latitude Is Left To The Commander To Accommodate His Decision Style. After successive estimates of the situation, the commander finally arrives at an action decision. "The responsibility for making this decision is solely that of the commander's, and the precise mental processes he uses in its formulation are his own concern." (Reference: Information Requirements Analysis, Marine Infantry Battalion, TCO Project Team MCTSSA, 16 June 1970). Although the operation's estimate is of value to the commander, in many cases the commander's decision will merely be an approval of the recommendation of the staff The way the commander relates to his staff is, to a large extent, conveyed in his planning guidance in which his policies are announced or reaffirmed.

Previous Experience Plays A Major Role. When issuing planning guidance, the commander often includes broad and general courses of action which he particularly desires to be considered, as well as provides guideline examples of decisions taken in similar or related operations. His previous operational experience is, therefore, used to a great extent to generate viable alternatives. However, no feasible sequence of actions, which could lead to the accomplishment of the mission, should be rejected. All feasible courses of action should be examined, and the one which offers the best chances of success selected. The reasoning process leading to the decision should be orderly, and all factors affecting the situation evaluated. Previous experience, which is of such a great value in military art, is however, by its very nature, a biasing factor for alternative evaluation.

3. DECISION TASK TAXONOMY

3.1 Overview

The present project seeks to define a taxonomy of decision situations for the purpose of later matching these decision situations to decision aids. Decision situations are decomposed into two components:

(1) Decision task.
(2) Decision maker.

The scope of the decision-task taxonomy is to capture explicitly how decision tasks relate to decision-making requirements. For this purpose, three sets of elements have been chosen:

(1) Information requirements.
(2) Decision-task attributes.
(3) Functional requirements.

In our approach a decision task is viewed as a "black box" translating information (information requirements) into a decision. A decision task is characterized by a set of attributes which uniquely defines the conditions under which the decision task must be performed. Finally, a set of functional requirements uniquely defines the process leading to the decision by decomposing the task into decision-making functions which are required for decision task performance.

3.2 Information Requirements

For each of the decision tasks identified during the decision task identification phase, the information requirements were assessed. No specific classification scheme was used for the information requirements as the nature of the inputs did not clearly relate to decision-making requirements at that point. It is, anyhow, important to specifically know what these information requirements are to see how decision-tasks relate to one another and consequently have an overall picture of the decision-making environment under study.

Along these lines we should mention the existence of a taxonomy of tactical information (Koelln, 1976) which presents the following categories as constituting an exhaustive, non-redundant set of information requirements for tactical decision making by infantry officers:

(1) Orders of next senior command.
(2) Estimated enemy locations.
(3) Enemy strengths, characteristics, and capabilities.
(4) Terrain and weather.
(5) Friendly unit locations and current contact enemy.
(6) Subordinate, adjacent, and higher friendly unit strengths and missions assigned.
(7) Supporting arms available.
(8) Logistical support status and administration.
(9) Command and communications.

Estimates of the total size of memory required to embody the information requirements can be made using this framework.

From the analysis of decision tasks, however, a set of information requirement attributes was derived. This set is depicted in Table 3-1. A formal definition for each attribute is provided in Appendix A.

TABLE 3-1

INFORMATION REQUIREMENT ATTRIBUTES

TYPE
SIZE
PRIORITY
ACCURACY
RELIABILITY
SPECIFICITY
FAMILIARITY
AGE
VALUE
COST

3.3 Decision Task Attributes

Decision tasks have been characterized by different sets of attributes. Brown and Ulvila (1977) in a study aimed at "facilitating identification of appropriate amount and types of decison-analytic techniques to use in a given situation" were able to list about one hundred situation dimensions. Each attribute could take up to nine different values resulting into an enormous number of decision task classes.

In an attempt to describe the decision-making environment of Navy Task Forces, Payne, Miller and Rowney (1974) devised a taxonomy of decisions built around two sets of descriptors: (1) Navy terms and (2) decision analysis terms. The decision analytic measures included complexity, uncertainty, dynamics and values. Although only 13 dimensions of value were used, the possible measures of these dimensions were qualitative as the scope of that project was a mere description of decision tasks.

In a project for exploring the potentialities of Decision Analysis for aiding major decisions within the Department of Defense, Miller, Merkhofer, Howard, Matheson and Rice (1976) built a taxonomy of decision problems along three dimensions: (1) characteristics of decisions and decision environments, (2) characteristics of decision makers and (3) characteristics of the decision process. In our approach, however, we found an alternative way of structuring decision task problems more appropriate for the Marine environment. Decision process, for us, is what it takes to perform the decision task and that we called decision-making function or functional requirement. In addition, our scope was broader, Decision Analysis being only one among many possible decision-aiding techniques.

The taxonomy of decision task in the present project is aimed at decision-making requirements. The choice of the set of attributes reflects this particularity. In the process of attribute definition, an attempt was made toward satisfying properties like those desirable for an attribute set as suggested by the framework of utility theory (Keeney and Raiffa, 1976): namely, that it be complete, so that it covers all aspects of the problem; decomposable, so that the analytical process is simplified by breaking it down into parts; nonredundant, so that double counting of category impact is avoided; and minimal, so that the number of categories is kept to a minimum. Specifically, the following steps were followed:

(1) Literature search and expert interview: to maintain a list of operational, decomposable, nonredundant attribute dimensions for decision tasks.

(2) Completeness test: to identify the potential need for including other attribute dimensions to the list, by analyzing typical decision tasks.

(3) Attribute definition: to enhance the attribute dimension list by adding new attributes defined through an inductive process based on the decision task analysis results.

(4) Relevance test: to identify and eliminate attribute dimensions with constant values for all decision tasks, therefore resulting in a minimal list of attribute dimensions.

The list of the selected decision-task attributes obtained after step 1 is portrayed in Table 3-2 with the respective references. Going through steps 2 to 3 led to the definition of two new dimensions: Type 1/Type 2/Type 3 and Decision Making/Decision Execution. These attributes are fully

TABLE 3-2

DECISION-TASK ATTRIBUTES AND RELEVANT REFERENCES

ATTRIBUTE	REFERENCE
SINGLE ATTRIBUTE/MULTI-ATTRIBUTE	Keeney, R.L. and Raiffa, H. Decisions with Multiple Objectives: Preferences and Value Tradeoffs. NY: Wiley, 1976.
INDIVIDUAL/GROUP	Goodman, B.C. Actions Selection and Likelihood Ratio Estimation by Individuals and Groups, Organizational Behavior and Human Performance, 1972, 7(1), Feb. 1972.
STATIC/DYNAMIC	Rapoport, A. Research Paradigms for Studying Dynamic Decision Behavior, in Wendt & Vlek (Eds.) Utility Probability and Human Decision Making. Dordrecht, Holland, D. Reidel, 1975.
ONE SHOT/REPETITIVE	Slovic, P. Toward Understanding and Improving Decision, in Salkovitz (Ed.) Science, Technology and the Modern Navy, ONR, 1976.
CERTAINTY/RISK (UNCERTAINTY)	Lifson, M.W. Decision and Risk Analysis for Practicing Engineers, Boston, Cahners Books, 1972.
ABSTRACT (GENERAL)/CONCRETE (TASK SPECIFIC)	Slovic, P. Information Processing, Situation Specificity, and the Generality of Risk-Taking Behavior, Journal of Personality and Social Psychology, 1972, 22 (1), 128-134.
WELL DEFINED/AMBIGUOUS	Whittemore, B. and Yovits, M. A Generalized Conceptual Development for the Analysis and Flow of Information, Journal of the American Society for Information Science, 1973, 221-231.
TIME CRITICAL/TIME RELAXED	Wright, P. The Harassed Decision Maker: Time Pressures, Distractions, and the Use of Evidence, Journal of Applied Psychology, 1974, 59(5), 555-561.
SMALL PROBABILITY HIGH LOSS/ NORMAL RANGE	Slovic, P., Fishhoff, B., Lichtenstein, S., Corrigan, B. and Combs, B. Preference for Insuring Against Probable Small Losses: Insurance Implications, The Journal of Risk and Insurance, 1977, XLIV (2), 237-258.

described in Appendix B. After step 4, the attribute abstract/concrete was dropped since it was realized that all decision tasks were described in task specific terms. Except for attributes abstract/concrete and Decision rule which were dropped, the attribute set obtained is identical to that of Saleh, et. al., (1978) which was aimed at describing Navy decision tasks for the purpose of defining decision-training requirements.

3.4 Functional Requirements

The functional requirements associated with a particular decision task are the decision-making functions to be executed by the decision maker to perform the decision task in conformity with the principles of decision analysis. They therefore assume a normative model of decision making. A set of functional requirements describing the possible formal steps a decision maker must go through to perform a decision task is depicted in Table 3-3 and described in detail in Appendix C.

3.5 Classification of Decision Tasks

For each of the decision tasks identified during the decision-task identification phase, information requirements, decision-task attributes and functional requirements were assessed. To illustrate the process an example follows.

In paragraph 2409 of FMFM 3-1 the task called "Selection of Landing Areas" is described as depicted in Figure 3-1. It is clear that this decision task, can actually be decomposed into two subtasks:

(1) Designate landing areas.
(2) Select primary and alternate landing areas.

a. <u>General</u>. --The landing area is that part of the objective area within which the landing operations of an amphibious task force are conducted. It comprises the sea, air, and land areas required for executing and supporting the landing and establishing the beachhead selected by the landing force commander. When the amphibious task force is composed of two or more attack groups with related landing groups, a landing area may be assigned to each attack group.

b. <u>Alternate Landing Areas</u>. --The landing area selected must satisfy both naval and landing force requirements. Accordingly, several alternate areas may be taken under consideration in the planning phase.

c. <u>Designation of Landing Areas</u>. --The amphibious task force commander delineates the sea areas and airspace required for the establishment of each beachhead tentatively selected by the landing force commander. The amphibious task force commander designates the combinations of sea and beachhead areas and airspace as possible landing areas, and indicates their relative desirability from a naval viewpoint. This designation is made after reviewing the naval considerations shown in figure 10.

d. <u>Primary and Alternate Landing Areas</u>. --The landing force commander selects primary and alternate landing areas from among those designated by the amphibious task force commander. The landing force commander maintains continuous liaison with interested commands to ensure that there is complete understanding concerning any restrictive considerations. The landing force commander selects those landing areas

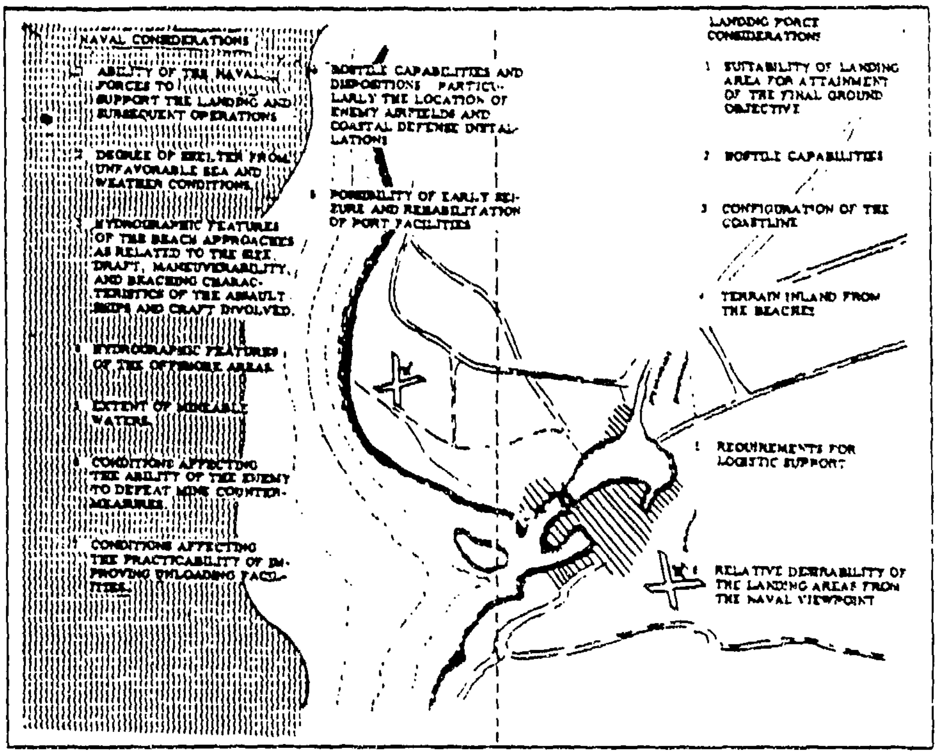


Figure 10. --Selection of Landing Areas.

which, consistent with the ability of the surface and air forces to provide support, will best facilitate the accomplishment of the landing force mission. In determining the desirability of landing areas from the viewpoint of the landing force, the considerations shown in figure 10 are also considered. The landing force commander presents his final selections to the amphibious task force commander for his concurrence and a statement of his ability to support operations in the selected areas with the forces assigned.

FIGURE 3-1.
SELECTION OF LANDING AREAS (FROM FMFM 3-1 pp. 89-90)

TABLE 3-3

INTERVIEW RESULTS:
COMPARE FRIENDLY COURSES OF ACTION

Decision Task: Compare Friendly Courses of Action

Inputs

Mission from Commander or higher HQ
Task Organization
List of C/A's under consideration
Support Plan
- Fire
- Air

Other Staff Estimates
- Enemy Situation
- Logistics
- Friendly Personnel Situation (location, morale, training status..)

Characteristics

Multi-Attribute
Individual
Static
One Shot
Risk
Concrete
Well Defined
Decision Making
Time Relaxed
Normal Range
Type 2

The first task is labeled with the keyword "designate" which is not a decision-making keyword. This task in turn can actually be decomposed into two subtasks:

(1) Define landing areas (since to each beachhead could correspond more than one landing area).
(2) Rank landing areas by degree of desirability from a naval viewpoint.

Consider the task "designate landing areas". Its characteristics are:

(1) Multi-attribute - since there are many dimensions of value to be considered as listed on Figure 10 of FMFM 3-1 depicted in Figure 3-1.

(2) Individual - since the CATF makes the decision alone.

(3) Static - since the outcome set does not change with time.

(4) One Shot - since the decision is to be made only once during the mission.

(5) Uncertainty - since the enemy capabilities are formally considered in the decision-making process.

(6) Concrete - since the decision problem is posed in task-specific terms.

(7) Well Defined - since the alternative set is completely describable and well-defined.

(8) Decision Making - since there is no fixed procedure or prescription to rank the alternatives.

(9) Time Relaxed - since the planning phase for an amphibious operation typically takes weeks.

(10) Normal Ranges - since this task is clearly envisioned and described in the framework of conventional warfare* and in this case, although very high losses might be incurred, the probabilities fall within normal ranges.

(11) Type 3 - since for each beachhead the CATF has first to generate all the possible sea and airspace areas required to establish the beachhead and choose one which will be designated as a landing area (alternative generation and selection). Then the CATF must rank the feasible landing areas by desirability according to the set of dimensions of value defined in the picture of Figure 3-1 (alternative selection).

To formally execute the task "designate landing areas" the following functions have to be performed:

(1) Alternative Development - which includes:

(a) Recognition of Option Existence and Constraints as the CATF might dismiss certain landing areas being obviously impractical. In addition, constraints on the way sea and airspace areas have to be associated with beachheads must be defined.

---

*In general, the Initiating Directive contains provisions and guidelines for the possible use of nuclear, biological and chemical warfare.

(b) Establishment of Plausibility Domains on the plausible alternatives based on the identified constraints.

(c) Formulation of Courses of Action by considering the plausibility domains on alternatives.

(2) Alternative Evaluation and Selection

(a) Criterion Assignment - since the CATF has to identify and select attributes for the evaluation of sea and air-space areas which, together with the beachhead, will constitute the landing areas. Furthermore, a criterion to aggregate these attributes leading to the selection has to be defined. Similarly, a criterion to aggregate the nine attributes of value prescribed by the doctrine to assess the relative desirability of the landing areas has to be defined.

(b) Value Assignment - since values for each of the attributes must be assigned.

(c) Analysis of Outcomes and Impacts - since the values must be aggregated to yield a single value for each alternative; selection or ranking can then be performed.

The task "select primary and alternate landing areas" has the same characteristics as "designate landing areas" except for #2 which is performed in group since the CATF has to concur on the CLF's choice, and #11 which is Type 2 as only a ranking of alternatives has to be performed. The functional requirements for this task are criterion and value assignment and analysis of outcomes and impacts. The results of the overall analysis are depicted in the MAB Decision Task Analysis Supplement, in which the decision tasks identified within the MAB environment together with inputs, attribute values and functional requirements are listed.

3.6 Interview Results

To ascertain the validity and adequacy of the classification process, it was decided to conduct a guided interview of Marine Corps personnel. This was done in sequence after the decision task identification/verification phase of the interview described in 2.2.3. For this part of the interview, Marine Corps personnel determined through a guided interview, the information requirements and the task characteristics of selected decision-tasks. The tasks included those selected by Perceptronics as well as those suggested by Marine Corps personnel. The task characteristics were elicited through discussion of the decision process involved in the particular decision tasks. A more detailed discussion follows.

(1) Operations. The decision task discussed was "Compare Friendly Courses of Action" which is part of the Operations Estimate. The classification results are depicted in Table 3-3. The salient features which came out of the discussion are the following:

(a) Although, in this task, many people are involved in providing information the G3 only has responsibility for the actual comparison, consisting of listing the advantages and disadvantages of each course of action contemplated. On the basis of that list of advantages and disadvantages, the G3 makes a recommendation on the course of action (C/A), presenting the greatest chance of success. However, the way this is done is not specified. The recommendation is then presented to the commander for approval or rejection.

(b) Although no C/A is neglected and decisions made are constantly questioned as the planning phase develops and more information is received, the operations estimate has been classified as One Shot.

(c) Although risks are clearly involved at the high echelon, the doctrine does not call for a specific way of embodying them in comparing friendly C/A's. However, the friendly C/A's are formally matched against the C/A's the enemy is most likely to adopt. At Battalion level, on the other hand, personnel are closer to the field and develop a "feel" for what the enemy will do when faced with the contemplated C/A's; this leads tactical commanders at Battalion level to accept only 0 or 1 probabilities.

(d) In the preliminary planning phase at Divison level, although the decision is constantly questioned, there is plenty of time to make it (typically a few days). On the contrary, at Battalion level, by the time the orders have been spelled out and the Commander has to come up with a decision or plan, there is actually very little time to go through a formal process and the time criticality is relatively high. While higher level decisions are in general time-relaxed, they can be very much time-critical at Battalion level (see also Information Requirements Analysis - Marine Infantry Battalion, Final Report, MCTSSA, TCO Project Team, 16 June 1976).

(2) Intelligence. The decision task discussed was "Determine Impact on Mission of Enemy Capabilities" which is part of the Intelligence Estimate. The classification results are depicted in Table 3-4. The main points made by the interviewee were the following:

TABLE 3-4

INTERVIEW RESULTS:
DETERMINE IMPACT ON MISSION OF
ENEMY CAPABILITIES

Decision Task: Determine Impact on Mission of Enemy Capabilities

Inputs

Mission Statement
List of Enemy Capabilities
Friendly Forces Information (Unit List or Task Organization)
Objectives Determined by Commander
C/A's under Formal Consideration
Terrain (Trafficability, Line of Sight)
Weather
D-Day

Characteristics

Multi-Attribute
Individual
Static during Planning Phase/Dynamic during Control Phase
Repetitive
Risk
Concrete
Well Defined
Decision-Making
Time Relaxed during Planning Phase/Time Relaxed to Time Critical during Control Phase
Normal Range
Type 2

(a) In the early planning phase, the G2 is asked for a briefing by the commander. At that time, the G2 performs this task but his estimate is formulated in very loose terms. The task is later performed carefully and no enemy capability is discarded from consideration, for an unlikely enemy alternative might suddenly become an obvious course of action for him in view of a new intelligence indicator.

(b) Static and time relaxed during the planning phase, this task is dynamic and time critical during the operations phase.

(c) The difference between higher level such as Division and lower level such as Battalion was pointed out again. While at higher echelon the Intelligence officer gets an abstract picture of the situation, at lower echelon, closer to the field and handling more limited information, the Intelligence officer needs less time for his analysis. At Battalion level for example, the time available for the formal decision-making process between reception of fragmentary orders and actual action may be very short, typically, one hour, while at Division level typically a few days to a few weeks are allowed.

(3) Fire and Air Support. The function of Fire and Air Support was viewed from a decision-analysis standpoint as the richest. Very intricate, embodying an enormous arsenal of possible fires, necessitating close coordination of a large number of agencies and people, it provided a terrain very rich in decision tasks. Two experts were interviewed, one for fire support and the other for air support.

The first task chosen was: "Monitor Requests for Fire Support" (see Table 3-5), which is part of fire and air support control, and the main features of this task were described by the interviewee as follows:

(a) Many factors enter into consideration for the choice of the fire to allocate to a request. The problem is one of the resource allocation type. Once a fire has been identified, which fits pretty well the requirements, it is selected. In other words, a "satisfycing" type of criterion is used for alternative selection.

(b) When the list of items describing the target and defining the requirements is very long, the response to the request is either "Yes I can do it" or "No I do not have the fire you requested." In other words, if the request is very well formulated, the decision-making process is simple, while if the request is not precise, the decision-making process is more complicated, requiring reasonable assumptions to be made about the missing data and appraising if a possible solution is good enough.

(c) The uncertainty factor is treated differently according to the application. When troop safety is concerned, the attitude of the command is not to take chances. For instance, if an indirect fire support request lists a target in the vicinity of friendly units, the request will not be supported.

TABLE 3-5

INTERVIEW RESULTS:
MONITOR REQUESTS FOR FIRE SUPPORT

Decision Task: Monitor Requests for Fire Support

Inputs

- Requests and within each request an item such as target location and descriptors, type of weapon to be used...
- Means or assets i.e., fires available (indirect, NGF, air), how far from the fire to the target, supply and resupply rates etc...
- Impacting factors such as weather, terrain, status of friendly forces.

Characteristics

Multi-Attribute
Group
Dynamic
Repetitive
Risk
Concrete
Well Defined
Decision Making
Time Relaxed
Normal Range
Type 3

The other task discussed in the area of Fire and Air Support was "Prepare Aviation Estimate of Supportability" (see Table 3-6). The salient features of the interview were the following:

(a) Computation of the requirements hinges on availability of loss rates estimates for which the rule employed is merely "best guess."

(b) The format of a supportability estimate is the same regardless of its type, whether it is logistics, fire support, etc. In the particular instance, for each C/A contemplated, advantages and disadvantages from an Air standpoint are listed. The conclusions, expressed in the form of a ranking, are drawn subjectively. Although the reasons behind the choice are explicit, the actual quantitative method leading to the ranking is not.

(c) When asked about the ranges involved (small probability high loss or normal ranges) the interviewee insisted on small probability/high loss which seemed counter intuitive in the context of conventional warfare. In fact, the interviewee remembered, during an operation in Vietnam, having landed on supposedly secured airfield and being shot at. The perceived loss, of course, was very large (loss of life) but the probability that the airfield might actually not have been secured, although low, was not unusually low. This shows that an officer having field experience might assign somewhat different values from what a decision analyst would assign. This advocates the use of guided interviews.

TABLE 3-6

INTERVIEW RESULTS:
PREPARE AVIATION ESTIMATE OF SUPPORTABILITY

Decision Task: Prepare Aviation Estimate of Supportability

Inputs

Air Support Requirements

Assets

- platforms
- locations
- parameters
- (payload,...)
- sortie rates
- loss rates etc...

Available Airfields/Carriers within Area of Operations

Weather

Characteristics

Multi-Attribute

Group

Static

One Shot

Certainty

Concrete

Well Defined

Decision Maker

Time Relaxed

Normal Range

Type 2

(4) Logistics and Personnel. During the last interview, the task "Compare Courses of Action from a Personnel Standpoint" (see Table 3-7), which is part of the Personnel Estimate, was discussed. The point was made again that, although at a high echelon of command there is plenty of time to make a decision, at lower echelon there is always very little time. The particular task under discussion is, however, almost never a real-time task.

The expert interviews provided useful feedback by establishing the feasibility of the proposed methodology for decision-task identification and classification. It appeared that the highest accuracy for attribute value assessment can be obtained by decision analysts interviewing Marine Corps personnel, since no written document can replace actual experience.

3.7 MAB Decision Task Clusters

The classification process previously described yielded a list of some 129 decision tasks along with their respective information requirements, characteristics and functional requirements.

To reduce the dimensions of this set it was attempted to identify classes with common attributes. Since this reduction requires extensive analysis of the data, it could not be carried out manually. Therefore, a sorting program was written on PDP 11-45 minicomputer, allowing the identification of decision-task classes. The distribution of MAB decision task classes is depicted in Figure 3-2. Fifty-two (52) different classes were identified out of which 29 consist of one element only, and the largest class size encountered was 17. The task of matching decision aids to decision task attributes is consequently very much simplified by this relatively small number of classes.

TABLE 3-7

INTERVIEW RESULTS:
COMPARE COURSES OF ACTION
FROM A PERSONNEL STANDPOINT

<u>Decision Task</u>: Compare Courses of Action from a Personnel Standpoint

<u>Inputs</u>

List of C/A's
What Units Are Involved
State of Training
Table of Organization for Unit
Inputs from G2 and G3
Replacement Status (location, how fast...)

<u>Characteristics</u>

Multi-Attribute
Individual
Static
One Shot
Certainty
Concrete
Well Defined
Decision Maker
Time Relaxed
Normal Range
Type 3

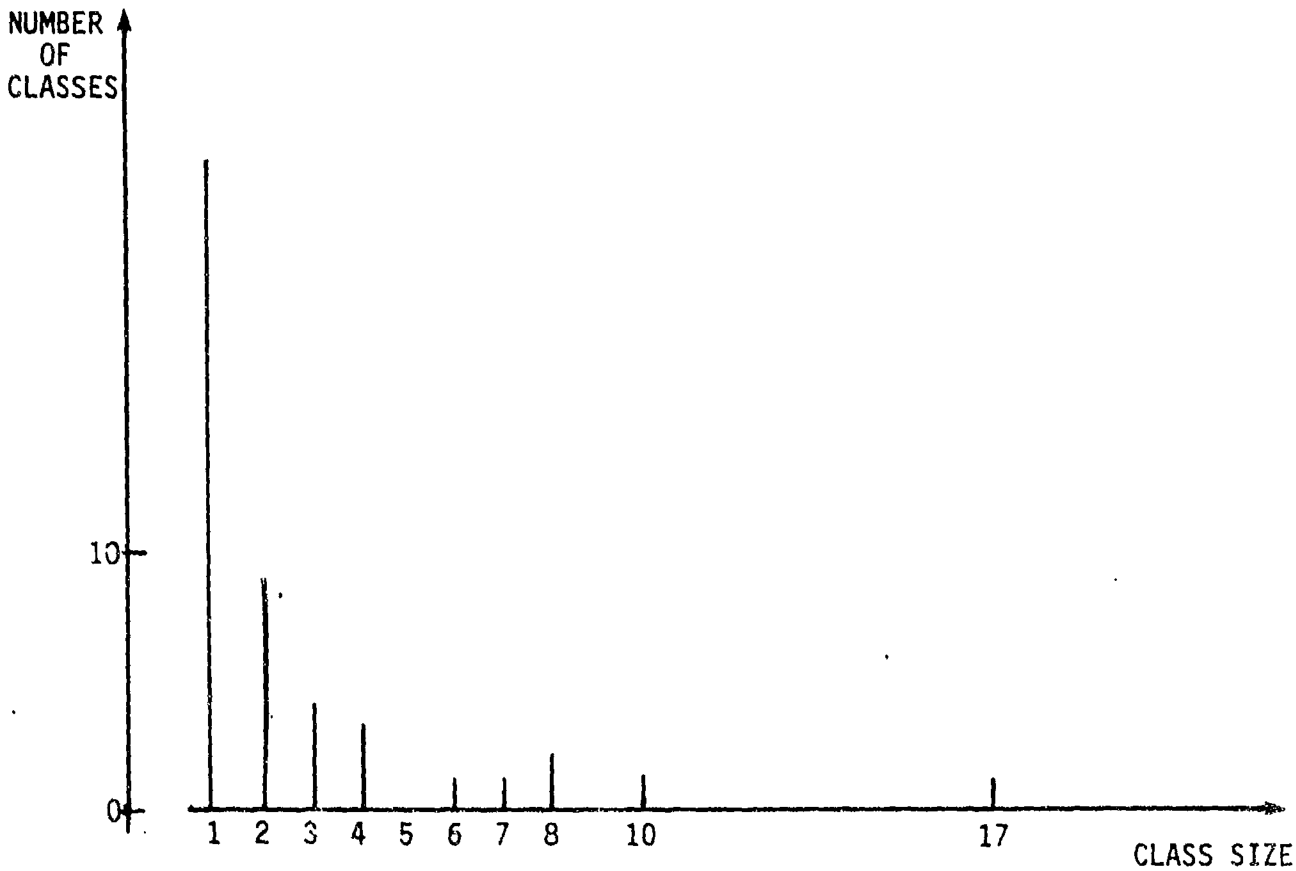


FIGURE 3-2.
DISTRIBUTION OF MAB DECISION TASK CLASSES

In an analytical effort aimed at building a meaningful description of the MAB decision-making environment in Marine Corps terms, the decision tasks were hierarchically classified in functions and subfunctions (e.g., Operations which includes Preliminary Planning and Detailed Planning). For each subfunction, a general tendency or "pattern" was then identified. This information is very helpful since decision aids for a given subfunction should be designed in view of the set of characteristics describing the subfunction general tendency. The results of this analysis are depicted in Table 3-8 in which, for each subfunction, the set of features, which have a value approximately constant for all tasks within the subfunction, are given.

TABLE 3-8

DECISION TASK PATTERNS

FUNCTION	GENERAL TENDENCY*
OPERATIONS	
Preliminary Planning	G/ST./O.S./R/D.M./T.R./N.R.
Detailed Planning	G/ST./O.S./C/W.D./D.M./T.R./N.R.
Control	G/D./REP./W.D./D.M./T.C./N.R./2,3
INTELLIGENCE	
Estimate	I/ST./O.S./A./D.M./T.R./N.R./S
Planning	W.D./D.M./T.R./N.R.
FIRE AND AIR SUPPORT	
Estimate	ST./O.S./C./W.D./D.M./T.R./N.R./S
Planning	G/O.S./C./W.D./T.R./N.R./3
Control	G/D/REP./W.D./D.M./T.C./N.R./3
PERSONNEL AND LOGISTICS	
Estimate	I/ST.O.S./C/W.D./D.M./T.R./N.R./2
Planning	G/ST./O.S./C/W.D./T.R./N.R./2,3
Control	G/D./REP./R.W.D./D.M./T.C./2,3

* Legend

I	= Individual	W.D.	= Well Defined
G	= Group	A	= Ambiguous
ST.	= Static	T.C.	= Time Critical
D	= Dynamic	T.R.	= Time Relaxed
O.S.	= One Shot	N.R.	= Normal Range
REP.	= Repetitive	1	= Type 1 (Problem Structuring)
C	= Certainty	2	= Type 2 (Alternative Selection)
R	= Risk	3	= Type 3 (Problem Structuring & Alternative Selection)

4. DECISION MAKER TAXONOMY

4.1 Overview

Although it is commonly accepted that decision-maker characteristics greatly influence the decision-making process, only a few studies were conducted to verify this hypothesis. MacCrimmon and Taylor (1975) discussed four attributes -- perceptual ability, information capacity, risk-taking propensity, and aspiration level -- and their influence on the decision strategies selected by decision makers. Building upon this study, Taylor and Dunnette (1974) assessed the influence on decision making of sixteen decision-maker attributes in the context of an experiment using manufacturing managers as subjects. These attributes included two demographic characteristics (age and experience in making personnel decisions) and fourteen scales measuring the psychological attributes of intelligence, motivation, personality traits, dogmatism, risk-taking propensity, cognitive complexity and vocational interests. In this experiment, Taylor and Dunnette quantified the relative contribution of decision-maker attributes to decision processes establishing conclusions such as high intelligence is associated with rapid information processing and risk-takers tend to process information more slowly (suggesting that risk-takers actually do not disregard pieces of information as it is generally thought).

4.2 Decision Style

In an attempt to introduce user-oriented principles in the design of decision support systems, Levit, et al, (1977) devised a taxonomy of decision style (defined as *"the characteristic and self consistent way an individual uses information in the decision-making process"*) built around three dimensions (1) abstract/concrete -- which relates to the information acquisition process, (2) logical/intuitive -- which relates to information assimilation and (3) active/passive -- which relates to action selection. As stated by Levit, et al, (1977) in their study,

> *"Decision style provides a mechanism for understanding the nature of individual variability in decision making and it is this understanding that has shown to be crucial in the design of information systems."*

The general conclusion drawn by Levit, et al, (1977) about decision style and the way it relates to decision aiding is that decision aids should be adaptive to various decision styles so as to minimize performance deterioration and restructuring efforts occuring when personnel change.

Lucas and Ruff (1977) reached the same conclusions as Levit, et al, (1977) insofar as adaptiveness is a virtue that decision aids should possess in general. Their definition of decision style, however, was somewhat narrower than that of Levit, et al, (1977) connecting decisions with the quantity of information presented to the decision maker, the rationale being that *"Some decision-makers require very detailed information to make a decision; others require only an overall assessment of the situation. The more detailed information just gets in their way."*

The way Marine Corps officers relate to tactical information was the object of an experimental study (Koelln, 1976) utilizing Marine Corps infantry officers stationed at Camp Pendleton and at the San Diego Marine Corps Recruit Depot as subjects. For the purpose of the study, tactical information classes were devised (see Section 3.2 of the present report) which were used as a basis to assess information preferences. One of the objectives of the study was to assess whether individual policies exist among Marine Corps officers as to the relative value of increasing amounts of tactical information in different categories.

The main result of the study is that data gathered tend to support the existence of an information utility function for individual officers. Furthermore, the study established the existence of two distinct groups; one group, with the largest effective, emphasized categories of information containing guidance from higher levels of command, while the second wanted more information about the environment external to the organization. Although not very conclusive in identifying major differences in attitude towards information for Marine Corps officers, this study tends to support the view that being adaptive is probably a virtue for a decision aid.

4.3 Decision-Maker Attributes

Except for decision style, which had already been the object of a study, no data were available for decision makers as they relate to decision tasks in the Marine Corps. It was consequently attempted in this research to establish a useful and effective set of decision maker attributes via consultation with relevant literature and expert opinion. A step-by-step procedure similar to that utilized for the definition of the decision-task characteristics was followed to define the set of decision-maker characteristics.

A working set of attributes was tested for completeness and relevance via interviews with Marine Corps personnel based at MCTSSA. The resulting attribute set, depicted in Table 4-1 reflects our consensus with interviewed Marine Corps personnel on what attributes related to decision makers possibly hinge on decisions at MAB level. A description of these attributes follows.

Grade. The grade is intended, as it is in general, in military organizations. For instance, the landing force commander of a MAB operation is a Brigadier general.

TABLE 4-1

DECISION MAKER ATTRIBUTES

- GRADE
- SPECIALTY
- FUNCTION
- FIELD EXPERIENCE LEVEL
- TRAINING LEVEL
- EDUCATION
- RISK ATTITUDE

<u>Specialty</u>. Specialties are defined in the Military Occupation Specialties document. Each specialty is referenced with a specific code number, e.g., 0302 Infantry Officer, 0202 General Intelligence, 0210 Counter Intelligence. Each specialty carries a minimum training level.

<u>Function</u>. Functions refer to a specific job within a task organization (T/O). They are clearly defined in FMFM 3-1 Command and Staff Action which sets forth the basic principles underlying task force organization. Task force organizations are, however, not fixed from one operation to another, but depend upon the type of operation envisioned and are defined by MAB headquarters in a T/O.

<u>Field Experience Level</u>. This attribute defines how much actual operations experience an officer possesses. Experience is a dominant factor in the military. Previous decisions made in actual operations most certainly influencing, as biasing factors, new decision problems.

<u>Training Level</u>. Training acquired in a specific military function hinges on the level of confidence an officer might have on his decision-making abilities and consequently should be a decisive factor in his approach to task performance. An officer with a low training level in his function might be receptive to certain structuring techniques for the decisions he is responsible for.

<u>Education</u>. Education of Marine Corps officers ranges from a high-school diploma to advanced degrees. This attribute probably hinges on the acceptability of certain aids which require special knowledge such as understanding of probabilities or utility theory. In general, aids might also be used more properly by people more knowledgeable technically. The curricula of Marine Corps schools can be used in determining the minimum level of skill in standard techniques such as decision analysis or operations research for each grade.

Risk Attitude. In general, risk attitude influences to a great extent decision-making behavior. There are obviously many different risk attitudes in the Marine Corps but they are not allowed to be expressed. The general attitude is to teach caution as a virtue and the emphasis on the use of a doctrine of enemy capabilities in the Marine Corps substantiates this claim. Variations from a decision maker to another should therefore be confined in the risk averse end of the scale.

4.4 Conclusions

After the final attribute set (Table 4-1) was established, the attributes were tested for redundancy. Furthermore, the relationships existing between them were elicited from Marine Corps personnel based at MCTSSA. Unexpectedly, it was learned that attributes (1) Field Experience Level, (2) Training Level, (3) Education and (4) Risk Attitude take values which are random within personnel assembled for a MAB operation. In other words, there is no conversion between the job assigned in a T/O and the value of the above attributes. The only attributes whose values are related to position assignments in the T/O of a MAB operation are (1) Grade, (2) Specialty and (3) Function. These three attributes, however meaningful from a military standpoint, cannot be related to decision-making qualities of deficiencies. Our general conclusion for the decision maker taxonomy was, therefore, that decision situations can be regarded as identical to decision tasks in terms of functional requirements and that, generally speaking, decisions aids for the Marine Corps should be adaptive if possible.

5. DECISION AID TAXONOMY

5.1 Approach

A survey of available decision aid taxonomies was conducted. Reviewed taxonomies included:

(1) Brown, R.V. and Ulvila, J.W. "Selecting Analytic Approaches for Decision Situations," 1977, DDI TR 77-7-27. Also Brown, R.V., speech delivered at the ONR Decision Taxonomy Workshop on March 2, 1979, Arlington, VA. Sponsor: ONR.

(2) Peterson, C., Phillips, L., Randall, L. and Shawcross, W. "Decision Analysis as an Element in an Operational Decision Aiding System," 1977, DDI PR 77-4-6. Sponsor: ONR.

(3) Miller, A., Rice, T. and Metcalfe, M. "An Analytic Characterization of Navy Command and Control Decision," 1979, ADA Final Report. Also Miller, A., speech delivered at the ONR Decision Taxonomy Workshop on March 2, 1979, Arlington, VA. Sponsor: ONR.

(4) Levit, A., Alden, D., Erickson, J. and Heaton, B. "Development and Application of a Decision Aid for Tactical Control of Battlefield Operations: A Conceptual Structure for Decision Support in Tactical Operations Systems," 1977, ARI TR-77-A2. Sponsor: ARI.

(5) Payne, J., Braunstein, T., Ketchel, J. and Pease, C. "A Brief Survey of Potential Decision Aids for the Task Force Commander and His Staff," 1975, SRI Research Memorandum NWRC-RM-84. Sponsor: ONR.

(6) Strieb, M., Martel, R. and Zachary, W. "Decision Aiding Opportunities in Naval Air ASW" briefing charts from a speech delivered at 43rd Military Operations Research Society Symposium, June 19-21, 1979, West Point. Sponsor: ONR.

(1) and (2) cover only part of the possible decision-aiding techniques, namely decision-analytic techniques. In (1) a framework is developed which assists decision aid developers in assessing the amount of decision analysis and what type of decision-analytic techniques are suitable for a given decision situation. In (2) which is along the same lines as (1), specific decision-analytic modules are defined and matches against decision tasks. Our classification of the available decision-analytic techniques took the results of (1) and (2) into account.

(3) and (4) present taxonomies which are very well thought out and cover the problem in its entirety but are at very high level. Although likely to be difficult to use in fine-grained discrimination for decision-aid selection, taxonomies (3) and (4) are very useful for the purpose of description.

Item (5) lists a large number of decision-aiding techniques drawn from the fields of Decision Analysis, Operations Research, Computer Science and Human Factors. Our decision-aid classification was constructed on this pattern but was more hierarchically structured, attempting to show, at the same level in the hierarchy, categories defined with the same level of detail. The matching principles defined in (5) are summarized in a decision aiding technique x decision type matrix whose entries are subjectively assessed figures of merit.

Item (6) was communicated to us late and we could not devote to it all the attention it deserves. It contains a decision-aid taxonomy enumerating some 25 decision-aiding techniques arranged into six broad categories. For each of the identified techniques, the values of a set of attributes were assessed. Among these attributes are computational speed, computational space requirements, and hardware/software generality. Attribute values are discrete, described in linguistic terms such as slow or fast for speed, and small or large for storage, and these descriptions are mapped into numerical value ranges. For instance, slow means more than 60 sec. and large means more than 100 core (probably in bits or bytes although it is not specified).

One of the decision-aiding techniques identified in (6) is Artificial Intelligence (A.I.) methods which were assessed as taking an average amount of time (10-60 sec.) and a high amount of memory (more than 100). Since all Artificial Intelligence methods have in common the fact that they try to represent knowledge, it is probably true that they require large amounts of storage. However, there are so many Artificial Intelligence methods that it is very hard to assess storage complexity globally. This broad category should be further refined and the assessment made for subcategories. Furthermore, this assessment should be performed in more general terms such as linear, polynomial, exponential, super-exponential, etc. since specific assessments (such as 100k bytes) are implementation and machine dependent. Similar remarks can be made for speed. Although A.I. methods address problems which would take tremendous amounts of computations if attacked by other means, the use of heuristics can drastically speed-up the process of getting to a satisfactory solution. Since the availability of good heuristics is problem dependent, no global statement about speed can be made at least for A.I. methods in general. To summarize, although (6) provides very useful information, it is our belief that certain attributes (such as speed and storage) should be assessed for decision aids and not for decision-aiding techniques, unless the assessment is made in non-numerical terms. Using this assessment, cost estimates based on computational speed and storage estimates can then be performed in view of the projected technological status. (See Section 4 of the present chapter.)

A hierarchical classification of decision-aiding techniques was devised and is presented in this report. We listed not only recognized decision-aiding techniques, i.e., those which led to the development of actual aids but potential techniques as well. In other words, when an analysis suggested a possible decision aid, it was included in the list. Also listed were a number of Artificial Intelligence and Pattern Recognition techniques which are felt to have a great potential for decision-aiding.

It was then sought to identify how decision-aiding techniques can be related to decision situations. For each of the identified decision-aiding techniques a relevance vector linking decision-aiding techniques on the one hand and functional requirements on the other, was assessed. This allowed for the definition of plausible decision-aiding techniques on the grounds of their relevance to the functional requirements of a given decision situation. Then a relevance matrix, linking decision-aiding techniques to possible attributes of any given decision situation, was assessed thus relating decision-aiding techniques to decision situations on the basis of the second set of descriptors, namely decision-task attributes.

Since a decision aid is characterized not only by the decision-aiding technique it employs but also by the type of implementation that is chosen, a set of decision-aid characteristics which are implementation oriented was developed. These characteristics, called decision-aid features, can be linked to decision-task attributes and consequently relate also to decision situations. Finally, a taxonomy of decision-aid costs was developed thus completing the decision-aid taxonomy and laying down the foundations for matching principles which are the object of Chapter 6.

5.2 Decision-Aiding Techniques

5.2.1 Overview. It appeared very soon that a generally acceptable definition of a decision aid is actually hard to come by. After a comprehensive search through the literature on decision aids, Levit, et al., (1974) concluded that "...the working definintion of decision aiding is dependent on the assumption of the decision making framework from which it is derived."

There is a consensus, however, that decision aids should, somehow, increase decision-making performance. This increase can be provided either directly, using, for instance, a device eliciting values or indirectly, for instance, by providing accurate information, more rapidly, via automation, thus allowing more time for decision making. The latter viewpoint was taken by the TCO project team who expressed the following opinion:

> "Automation aids can enhance the mental processes used for making decisions by providing accurate and timely information" (TCO Overview, 18 February 1977, TSCRB, MCTSSA).

A similar viewpoint proposes to automate mundane tasks such as compiling lists or producing tables, thus resulting in more time for decision making and, hopefully, better decisions. In our review of decision-aiding techniques we included both types (i.e., direct and indirect) of decision aiding techniques. The techniques which were identified and analyzed fall into three main categories: (1) Decision Analysis, (2) Operations Research and (3) Computer Science. Table 5-1 presents a summary of these techniques while Table 5-2 provides relevant references for them.

5.2.2 Decision Analysis. Decision-analytic aids are generally based on normative models of rational behavior. Whether they cover the entire decision-making process or only part of it, they generally provide some kind of an answer which integrates judgments elicited from the decision maker. In this category, fall a number of software packages, such as DDI's Rapid Screening of Decision Options and Perceptronics' Group Decision Aid. Both are examples of aids which cover the entire decision-making process, contrasted by, e.g., DDI's Interactive Decision Analysis Aids for Intelligence Analysts which address only subproblems, such as probability assessment. Many computer-based decision analytic aids are designed in a man/computer task-sharing manner which optimizes their joint performance. In Bayesian decision-aiding for example, data evaluation is provided by the human and data aggregation performed by the computer. This approach was taken in PIP (Edwards, 1968) where experts assess $P(D|H)$ rather than $P(H|D)$ and a computing device aggregates these $P(D|H)$ judgements to arrive at a final posterior judgement.

These subcategories were distinguished depending on whether values and probabilities or both are considered. A similar categorization scheme was employed in a bibliography on Policy Optimizing Methodologies and Applications (Policy Studies Journal, Winter 1977). The methods of decision analysis are generally well established and a good general reference for them is Keeney and Raiffa (1976). Another important reference of a general nature is Anderson and Anderson (1976).

TABLE 5-1

DECISION-AIDING TECHNIQUES

DECISION ANALYSIS	VALUE MODELS	UTILITY ASSESSMENT TECHNIQUES MULTI-ATTRIBUTE UTILITY ANALYSIS COST-BENEFIT ANALYSIS DISCOUNTING MODELS MONTE CARLO METHODS GROUP UTILITY AGGREGATION
	PROBABILITY MODELS	PROBABILITY ELICITATION BAYESIAN UPDATING SENSITIVITY ANALYSIS GROUP PROBABILITY AGGREGATION
	PROBABILITY AND VALUE MODELS	SUBJECTIVE EXPECTED UTILITY PROBABILISTIC MULTI-ATTRIBUTE UTILITY ANALYSIS RISK-BENEFIT ANALYSIS DECISION TREE STRUCTURING GROUP DECISION ANALYSIS PARTIAL INFORMATION BASED DECISION ANALYSIS FUZZY DECISION ANALYSIS
OPERATIONS RESEARCH	ANALYTIC MODELS	WARFARE AREA MODELS LANCHESTER'S THEORY OF COMBAT GAME THEORY
	DETECTION AND SEARCH	TIME INVARIANT STATISTICAL DETECTION SIGNAL DETECTION SEARCH MODELING
	OPTIMIZATION METHODS	SIMULATION AND WAR GAMING SCHEDULING MATHEMATICAL PROGRAMMING
	FACILITATION TECHNIQUES	TACTICAL SIMULATION COVERAGE TEMPLATES TIME/DISTANCE ALGORITHMS
COMPUTER SCIENCE	INFORMATION MANAGEMENT	DATA BASE ORGANIZATION MAN-MACHINE COMMUNICATION MESSAGE PROCESSING
	PATTERN RECOGNITION	CLUSTERING CLASSIFICATION INFORMATION AND DISCRIMINATION MEASURES LINEAR DISCRIMINANT FUNCTIONS
	ARTIFICIAL INTELLIGENCE	PROBLEM REPRESENTATION PROBLEM SOLVING LEARNING SYSTEMS PATTERN-DIRECTED INFERENCE SYSTEMS PLANNING MECHANISMS

TABLE 5-2

RELEVANT DECISION-AIDING TECHNIQUE REFERENCES

TECHNIQUES	REFERENCES
UTILITY ASSESSMENT TECHNIQUES	Johnson, E. and Huber, G. "The Technology of Utility Assessment", IEEE Trans. on Systems, Man and Cybernetics, 1977, 7(5):311-325.
	Knepprath, M., Hoessel, W., Gustafson, D. and Johnson, E. "Selecting a Worth Assessment Technique", API Technical Paper, June 1974.
MULTI-ATTRIBUTE UTILITY ANALYSIS	Shepard, R. "On Subjectively Optimum Selections Among Multi-Attribute Alternatives," in Shelley, M.W. and Bryan, G.L. Human Judgements and Optimality, Wiley, 1964, pp. 257-81.
	Edwards, W. "How to Use Multi-Attribute Utility Measurement for Social Decision Making", IEEE Trans. on Systems, Man and Cybernetics, 1977, 7(5):326-340.
COST-BENEFIT ANALYSIS	Keeney, R. and Raiffa, H. Decisions with Multiple Objectives: Preferences and Value Trade-offs, 1976, Wiley, New York.
DISCOUNTING MODELS	Keeney, R. and Raiffa, H. Decisions with Multiple Objectives: Preferences and Value Trade-offs, pp. 473.
MONTE CARLO METHODS	Gardiner, P. "Decision Spaces", IEEE Trans. on Systems, Man and Cybernetics, 1977, 7(5):340-349.
GROUP UTILITY AGGREGATION	Seaver, D. "Assessment of Group Preferences and Group Uncertainty for Decision Making," Social Science Research Institute, University of Southern California, Report 76-4, 1976.
PROBABILITY ELICITATION	Beach, L.R. and Phillips, L.D. "Subjective Probabilities Inferred from Estimates and Bets," Journal of Experimental Psychology, 1967, 75:354-359.
	Barclay, S., Brown, R.V., Kelly, C., Peterson, C., Phillips, L. and Selvidge, J. Handbook for Decision Analysis, Decisions and Designs TR-77-6-30, 1977.
BAYESIAN UPDATING	Phillips, L. and Edwards, W. "Conservatism in a Simple Probability Inference Task," Journal of Experimental Psychology, 1966, 72:346-354.
	Beach, B. "Expert Judgement About Uncertainty: Bayesian Decision Making in Realistic Settings," Organizational Behavior and Human Performance, 1975, 14:10-59.
SENSITIVITY ANALYSIS	Fischoff, B., Slovic, P. and Lichtenstein, S. "Improving Intuitive Judgements by Subjective Sensitivity Analysis", Decision Research PTR-1060-78-7, 1978.
GROUP PROBABILITY AGGREGATION	DeGroot, M.H. "Reaching a Consensus," Journal of the American Statistical Association, 1974, 69:118-121.
	Winkler, R.L. "The Consensus of Subjective Probability Distributions," Management Science, 1968, 915:61-75.
SUBJECTIVE EXPECTED UTILITY	Rapoport, A. and Wallsten, T. "Individual Decision Making," Annual Review of Psychology, 1972, 23:131-176.
PROBABILISTIC MULTI-ATTRIBUTE UTILITY ANALYSIS	von Winterfeldt, D. "An Overview, Integration and Evaluation of Utility Theory for Decision Analysis," Social Science Research Institute, University of Southern California, Report 75-9, 1975.
	Keeney, R. and Raiffa, H. Decisions with Multiple Objectives: Preferences and Value Trade-offs, [illegible]

TABLE 5-2 (COND'T)

RISK-BENEFIT ANALYSIS	Fischoff, B. "The Art of Cost-Benefit Analysis," Decision Research PTR-1042-77-2, 1977.
DECISION TREE STRUCTURING	Nickerson, R. and Feehrer, C. "Decision Making and Training: A Review of Theoretical and Empirical Studies of Decision Making and Their Implications for the Training of Decision Makers," 1975, BBN Report No. 2982.
	Merkhofer, M., Miller, A., Robinson, B. and Korsan, R. "Decision Structuring Aid: Characterization and Preliminary Implementation," 1977, SRI Report AP MER 7709.
GROUP DECISION ANALYSIS	Dalkey, N. "Group Decision Theory," UCLA-ENG-7749 School of Engineering and Applied Science, University of California, Los Angeles (1977).
PARTIAL INFORMATION BASED DECISION ANALYSIS	Fishburn, P. Decision and Value Theory, Publications in Operations Research No. 10, John Wiley & Sons, Inc. New York, 1964.
	Crolotte, A. and Salen, J. "A Partial Information Based Decision Aiding System for the Marine Battalion," 1979 Perceptronics PRTR-1061-79-2.
FUZZY DECISION ANALYSIS	Efstathiou, J. and Rajkovic, V. "Multi-attribute Decision Making Using a Fuzzy Heuristic Approach," IEEE Trans. on Systems, Man and Cybernetics, 1979, 9(6):326-333.
	Watson, S., Weiss, J. and Donnell, M. "Fuzzy Decision Analysis," IEEE Trans on Systems, Man and Cybernetics, 1979, 9(1):1-9.
WARFARE AREA MODELS	Shudde, R.H. "Special Probabilistic Models," "Contact and Attack Problems," "Hit Problems," in Selected Methods and Models in Military Operations Research, Zehna, P. (Ed.), U.S. Gov. Printing Office, Washington, 1971.
THEORY OF COMBAT	Shudde, R.H. "Lanchester's Theory of Combat," in Selected Methods and Models in Military Operations Research (op. cit.).
GAME THEORY	Haywood, O.G. "Military Decision and Game Theory," Operations Research, 1954, 2(4):365-385.
	Von Neumann, J. and Morgenstern, O. Theory of Games and Economic Behavior, 1947, Princeton University Press, Princeton, N.J.
TIME INVARIANT STATISTICAL DETECTION	Pollock, S.M. "Statistical Detection Models," in Selected Methods and Models in Military Operations Research (op. cit).
	Rapoport, A. "Detection of Change Processes," presented at the Symposium on Computer Aids to Decision Making in Command and Control Systems, April 18 and 19, 1979, Haifa University, Israel.
SIGNAL DETECTION	Sorenson, H.W. "Comparison of Kalman, Bayesian and Maximum Likelihood Estimation Techniques," in Theory and Applications of Kalman Filtering, Leondes C.T. (Ed.), NATO AGARDograph #139.
	Swets, J.A. (Ed.) "Signal Detection and Recognition by Human Observers," 1964, Wiley, New York.
SEARCH MODELING	Pollock, S.M. "Search Models," in Selected Methods and Models in Military Operations Research (op. cit.).
SIMULATION AND WAR GAMING	Andrus, A.F. "Simulation and War Gaming," in Selected Methods and Models in Military Operations Research (op. cit.).
	Gordon, G. System Simulation, 1978, Prentice-Hall, Englewood Cliffs, New Jersey.
SCHEDULING	Conway, R.W., Maxwell, W.L. and Miller, L.W. Theory of Scheduling, 1967, Addison-Wesley.
	Crowston, W.B. "Decision CPM: Network Reduction and Solution," Naval Res. Quart. 1970, 21: 435-452.

TABLE 5-2 (COND'T)

MATHEMATICAL PROGRAMMING	Simonnard, M. Linear Programming, 1966, Prentice-Hall.
	Mangasarian, O. Nonlinear Programming, 1969, McGraw-Hill, New York.
	Garfinkel R. and Nemhauser, G. Integer Programming, 1972, John Wiley & Sons, New York.
TACTICAL SIMULATION	Lafos, L. "Predictive Aids for Discrete Decision Tasks with Input Uncertainty" IEEE Trans on Systems, Man and Cybernetics, 1979, 8(1):19-29.
	Tactical Warfare Simulation, Evaluation and Analysis System (TWSEAS), DB 7-75, Commanding General, Marine Corps Development and Education Command, Quantico.
COVERAGE TEMPLATES	Pilette, S., Biggs, B., Edwards, L. and Martinek, H. "Optimum Patching Technique for Seismic Sensors Employed in a Grid," 1978, ARI Technical Paper 320.
TIME, DISTANCE ALGORITHMS	Cooper, J., Moore, M. and Halpin S. "Movanaid: An Interactive Aid for Analysis of Movement Capabilities," 1975, ARI Technical Paper 305.
DATA BASE ORGANIZATION	Wiederhold, G. Database Design, 1977, McGraw-Hill, New York.
	Brosey, M. and Shneiderman, B. "Two Experimental Comparisons of Relational and Hierarchical Database Models," Int. J. Man-Machine Studies, 1978, 10:625-637.
	Shneiderman, B. "Improving the Human Factors Aspect of Database Interactions," ACM Trans. Database System, 1978, 3(4):417-439.
MAN-MACHINE COMMUNICATION	Gaines, B.R. "Man-Computer Communication -- What Next?" Int. J. Man-Machine Studies, 1978, 10:225-232.
	Miller, L. and Thomas, J. "Behavioral Issues in the Use of Interactive Systems," Int. J. Man-Machine Studies, 1977, 9:509-536.
	Kozar, K. and Dickson, G. "An Experimental Study of the Effects of Data Display Media on Decision Effectiveness," Int. J. Man-Machine Studies, 1978, 10:495-505.
MESSAGE PROCESSING	Samet, M. "Automated Information Selection and Pacing," Proceedings 1979 IEEE Conference on Cybernetics and Society, Tokyo, Japan.
	Sagalowicz, D. "IDA," 1977, SRI Artificial Intelligence Center, Technical Note 144.
	Blum, R., Callahan, C., Graulich, M., Kinley, W. and Aitus, J. "Information Management for the Tactical Operations System (TOS)," 1979, Vector Research Technical Report FR 79-1.
CLUSTERING	Sokal, R. and Sneath, P. Principles of Numerical Taxonomy, 1963, Freeman, San Francisco.
	Zahn, C. "Graph-Theoretical Methods for Detecting and Describing Gestalt Clusters," IEEE Trans. on Computers, 1971, [illegible]:68-86
CLASSIFICATION	Fu, K. Sequential Methods in Pattern Recognition and Machine Learning, 1968, Academic Press, New York.
	Cover, T. and Hart, P. "Nearest Neighbor Pattern Classification," IEEE Trans. on Information Theory, 1967, 13:21-27
	Dasarathy, B. and Sheela, B. "A Composite Classifier System Design: Concept and Methodology," Proceedings of the IEEE, 1979, [illegible]

TABLE 5-2 (COND'T)

INFORMATION AND DISCRIMINATION MEASURES	Ben-Bassat, M. "f-Entropies, Probability of Error, and Feature Selection," Information and Control, 1978, 39(3):227-242.
	Toussaint, G.T. "Distance Measures as Measures of Certainty and Their Application to Statistical Pattern Recognition," First Conference of the Statistical Science Association of Canada, Kongston, June 4-6, 1973.
LINEAR DISCRIMINANT FUNCTIONS	Minsky, M. and Papert, S. Perceptrons: An Introduction to Computational Geometry, 1969, MIT Press, Cambridge.
	Smith, R. "Design of Multicategory Pattern Classifiers with Two-Category Classifier Design Procedures," IEEE Trans. on Computers, 1963, 18:548-551.
PROBLEM REPRESENTATION	Luger, G. "A State-Space Description of Transfer Effects in Isomorphic Problem Situations," Int. J. Man-Machine Studies, 1978, 10:613-623.
	Pearl, J. "A Goal-Directed Approach to Structuring Decision Problems," 1978. UCLA Report ENG-7811.
	Amarel, S. "On the Representation of Problems and Goal Directed Procedures for Computers," Commun. Am. Soc. Cybernetics, 1969, 1(2).
PROBLEM SOLVING	Nilsson, N. Problem-Solving Methods in Artificial Intelligence, 1971, McGraw-Hill, New York.
	Newell, A. and Simon H. "GPS, A Program That Simulates Human Thought," in Computers and Thought, Feigenbaum, E. and Feldman, J. (Eds.), 1963, McGraw-Hill, New York.
LEARNING SYSTEMS	Buchanan, B. and Mitchell, T. "Model-Directed Learning of Production Rules," in Pattern-Directed Inference Systems, Waterman, D. and Hayes-Roth, F (Eds.), 1978, Academic Press, New York.
	Griolotte, A. and Ben-Bassat, M. "Heuristic Learning," 1977, Perceptronics PR-1054-77-12.
PATTERN DIRECTED INFERENCE SYSTEMS	Hayes-Roth, F., Waterman, D. and Lenat, D. "Principles of Pattern-Directed Inference Systems," in Pattern-Directed Inference Systems, (op. cit.).
	Duda, R. Hart, P. and Nilsson, N. "Subjective Bayesian Methods for Rule-Based Inference Systems," 1976, SRI Artificial Intelligence Center, Technical Note 124.
PLANNING MECHANISMS	Sacerdoti, E. "Planning in a Hierarchy of Abstraction Spaces," Proceedings, Third International Joint Conference on Artificial Intelligence, August 1973.
	Nilsson, N. "Some Examples of AI Mechanisms for Goal Seeking, Planning, and Reasoning," invited paper XXI International Congress of Psycholoty Symposium No. 16 "Natural and Artificial Intelligence," Paris, July 19-23, 1976.

Of particular salience in this classification of decision-analytic technique is that it contains all the well-established techniques and more recently introduced techniques such as partial information based and fuzzy decision analysis. Although they have not yielded as yet a specific decision aid, these techniques show a very high potential for decision aiding and will possibly be implemented in the near future.

It should be noted that certain decision aids actually employ more than one decision-aiding technique. For example, Rapid Screening of Decision Options is composed of four modules which respectively utilize the following techniques: Probability Elicitation, Bayesian Updating, Multi-Attribute Utility Analysis and Subjective Expected Utility. Similarly, Perceptronics' Group Decision Aid (Leal, Levin, Johnston, Agmon and Weltman, 1978) uses Decision Tree, Subjective Expected Utility, Probabilistic Multi-Attribute Utility Analysis, Sensitivity Analysis and Group Decision Analysis. The fact that certain decision aids embody more than one decision-aiding technique should be taken into account in the decision-aid scoring procedure.

5.2.3 Operations Research. Operations Research techniques have been used for a long time for many decision problems in which an alternative must be chosen among a very large set of possible alternatives and the computations involved cannot possibly be carried out without the help of some sort of algorithm or procedure. Problems of this kind include traveling salesman (TSP), and more generally, resource allocation problems. Inputs to these aids are mainly parameters for which specific values are required. Outputs are optimal solutions in the forms of tables, lists or strategies. Along the same lines, in order to appraise the relative value of courses of action a commander could, for instance, use predictive simulation and make a decision on this basis. In such a case, the computer is being utilized as a computing device stricto sensu, and the interaction between the use and the aid occurs at the end of a "run" and consists of the user looking at numbers, entering the new parameter values and running the program again. This need not always be the case. In many instances tasks can be shared between human and computer as it is the case for some decision-analytic aids. Smith (1979) reports a computer-aided ship tracking technique in which the computer does automatically the part of the ship identification and leaves ambiguous identifications to the operator who makes some value judgment. The computer/operator system can go through a number of interactions in a highly interactive mode, via a graphic display to improve recognition performance. Similarly, Walsh and Schechterman (1978) report a significant performance improvement using what they call "operator aided optimization" (OAO) over unaided and machine aided decision making. In the OAO approach, the human helps the machine to help the human, i.e., principles of human factors are used to optimally allocate tasks between the human and the machine; this approach is similar to that mentioned above taken by Smith (1979).

The rationale behind the task sharing approach is that there are cases where manual performance exceeds that of automatic methods (Buck and Hancock, 1978). The techniques of Human Factors are used in designing decision aids using these principles, generally drawn from experiments. However, they are used only to optimize the implementation of the aid and consequently, the corresponding aids are classified under the O.R. category. Note that unlike for Decision Analysis techniques, a computer is generally required to implement Operations Research techniques and, that consequently, the principles of man-computer systems should be employed.

5.2.4 Computer Science. While decision aids were traditionally confined to using techniques pertaining to the fields of Decision Analysis or Operations Research, there was recently a shift toward the use of techniques from the field of Computer Science to improve decisions. Of particular salience is the increasing use of information systems to improve information flow between individuals and information timeliness and accuracy. The rationale behind R&D efforts such the Marine Corps TCO or the Army TOS is that improving information communication should increase decision-making effectiveness. Systems of this kind are generally built around a Data Base Management System and include displays, input devices, routing protocoles and software packages. An example of such a system specifically designed for decision aiding is DAISY developed at the University of Pennsylvania (Sinaiko, 1977). Another example of a decision support system built around a DBMS is the Picture Building System (Jacob, 1978) which consists of a color graphics terminal with image-mixing and a software package which serves as a display generation and management system. This system permits and facilitates algorithms which include the ability of humans to recognize patterns and process two-dimensional data structures. It provides support to the decision maker but does not provide a specific recommendation. It might consequently appeal to many users who are afraid that computers might take some prerogatives away from them.

The potential of Artificial Intelligence for decision aiding was already realized by Payne, et al., (1975). More recently, great emphasis was put on possible application of Adaptive Programming Technology, which includes Artifical Intelligence and Pattern Recognition methods, to the military environment (Shaket, Ben-Bassat, Madni and Leal, 1978). Pattern Recognition techniques had been already used for training (Cockrell, 1978) and can obviously be used for decision aiding. Due to the great importance of Computer Science Techniques and to the fact that very few studies analyzed them in view of their potential application for decision aiding, we have put more emphasis on them in our analysis. In particular, a detailed classification of these techniques was provided. It is portrayed in Table 5-3. Knowledge-Based Systems presently enjoy a phase of recognition due to unquestionable success in a number of areas. Among these

TABLE 5-3

COMPUTER-BASED DECISION-AIDING TECHNIQUES

DATA BASE ORGANIZATION

- Doubly chained list
- Inverted file
- Hash coding
- Directory file
- Hierarchical structure
- Sequential file
- Indexed-Sequential file
- Indexed file
- Direct file
- Multiring file
- Multi-level file
- Schema & subschema
- Relational Model

MAN-MACHINE COMMUNICATION

- Analog Techniques
  - Joysticks
  - Digitizing pads
  - Ball
  - Mouse
  - Lightpen
  - Potentiometers
- Symbolic Techniques
  - Input:
    - Keyboard
    - Lightpen
    - Touchpen
    - Touch panel
    - Switches
    - Menu selection
    - Q/A
    - Free format
  - Output:
    - CRT (b/w, color)
    - Lights
    - Touch feedback
    - Force feedback
    - Graphics/alphanumeric
    - Printers
    - Plots on paper
- Voice
  - Input:
    - Limited Vocabulary
  - Output:

MESSAGE PROCESSING

- Queuing
- Filtering & Selection
- Pacing
- Routing
- Standing Request
- Alert

CLUSTERING

- Similarity Measures
- Criterion Functions
- Hierarchical Clustering
- Graph-Theoretic Methods

CLASSIFICATION

- Bayes Decision Theory
- Nearest-Neighbor Rule
- Discriminant Functions
- Composite Classifier
- Multi-Membership Classification

INFORMATION AND DISCRIMINATION MEASURES

- α-Entropies
- Bhattacharyya's Coefficient
- Matusita's distance
- Generalized measures

LINEAR DISCRIMINANT FUNCTIONS

- Perceptron
- Gradient Descent
- Minimum Squared Error
- Potential Functions

PROBLEM REPRESENTATION

- State-Space
- And/Or graphs
- Means Ends
- Semantic Networks

PROBLEM SOLVING

- Search Methods
  - Depth First
  - Breadth First
  - Best First
  - Hill-Climbing
  - A*
  - Minimax
  - α-β
  - Bandwidth
  - Static Pruning
  - Dynamic Pruning
- Means Ends Analysis
- Problem Decomposition

LEARNING SYSTEMS

- Learning from examples
- Automatic Rule Learning
- Heuristic Learning

PATTERN-DIRECTED INFERENCE SYSTEMS

- Network-Based
- Rule-Based
  - Production
  - Transformation

PLANNING MECHANISMS

- Frames
- Transition Networks
- Petri Nets
- Procedural Nets
- Demons

successful Knowledge-Based Systems, the following are particularly important: (1) MYCIN (Shortliffe, 1976), (2) DENDRAL (Buchanan, Sutherland and Feigenbaum, 1969) and its companion program CONGEN, (3) MEDAS (Ben-Bassat, Carlson, Puri, Lipnick, Portigal and Weil), (4) INTERNIST (Pople, Myers and Miller, 1975) and (5) PROSPECTOR (Duda, Hart, Nilsson, Reboh, Slocum and Sutherland, 1977). A brief description of these systems together with their main characteristics is presented in Table 5-4. All the Knowledge-Based Systems developed or under development thus far belong to the category of Pattern-Directed Inference Systems (PDIS). For completeness, a taxonomy of these systems was included (see Figure 5-1).

5.3 Definition of Plausible Decision Aids

To any given decision situation, a set of functional requirements is associated. They represent decision functions which must be performed to accomplish the particular decision task and which, at the same time, are not provided by the decision maker.

Conversely, each decision-aiding technique relates to one or more functional requirements. This relation can be direct, i.e., a decision aiding technique can aim at a specific function, or indirect, if a decision-aiding technique hinges on a function it is not directly aimed at. The latter case can occur whenever a decision-aiding technique is designed for a specific function but still is relevant to the performance of another or if the decision-aiding technique is of a supportive nature, not really aimed at a specific function in particular. Whatever the case, it is possible to assess the entries of the decision-aiding techniques X functional requirement relevance matrix. The results of the assessment process are depicted in Figure 5-2. Although it is theoretically possible to assess the entries of this matrix with a

TABLE 5-4

CHARACTERISTICS OF A FEW SUCCESSFUL KNOWLEDGE-BASED SYSTEMS

	SYSTEM					
	MYCIN	Meta-DENDRAL	CONGEN	MEDAS	INTERNIST (now DIALOG)	PROSPECTOR
Application Area	Diagnosis and Treatment of Bacterial Infections	Generation of Production Rules (applied to Chemical Structures)	Chemical Structure Determination	Medical Diagnosis for Emergency and Critical Care	Medical Diagnosis and Consultation	Assistance for Mineral Exploration
Technique Employed	Production Rules	Learning of Production Rules	List Processing Algol-like Language	Multi-membership Classification	Production Rules and Semantic Network	Production Rules and Partitioned Semantic Network
Computer Used	DEC PDP-10	DEC PDP-10	DEC PDP-10	Data General Eclipse S/200	DEC PDP-10	DEC PDP-10
Operating System	TENEX	TENEX	TENEX or TOPS-10 or TOPS-20	RDOS	TENEX	TOPS-20
CPU Power	5-10 MIPS	5-10 MIPS	5-10 MIPS	1 MIPS	5-10 MIPS	5-10 MIPS
Response Time	Instantaneous to 10 sec depending on load	A few seconds to an hour depending on problem	15-20 min/problem (50-100 structural candidates/sec.)	instantaneous to a few seconds	15-20 sec. query (45 min/case)	app. 1 sec.
Memory Requirements	200 k words (900 k bytes)	256 k words	40 k words (200 k bytes)	112 k byte 10 m byte disk	~800 k bytes	>1000 k bytes
Development Effort	5-10 man-year/year since 1972	1½ man-year/year since 1973	3 man-year/year since 1971	2-4 man-year/year for 2-3 years	5-6 man-year/year since 1972 (expected 4 more years)	4-5 man-year/year for 5 years

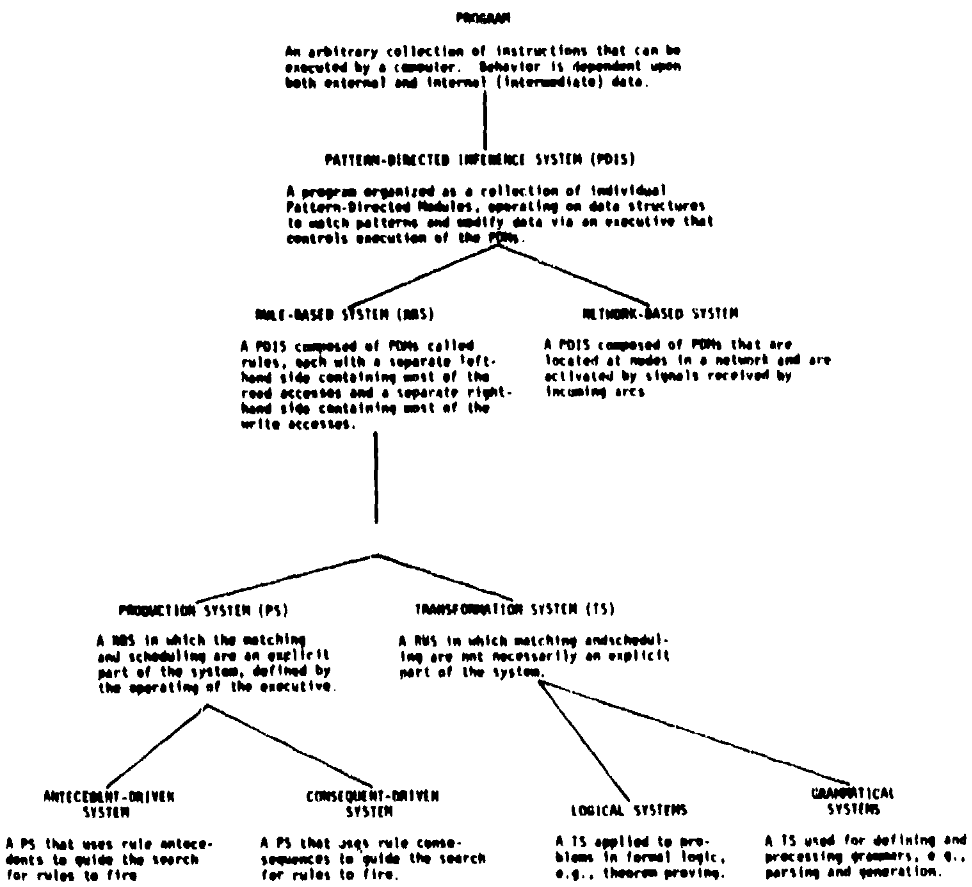


FIGURE 5-1.
TAXONOMY OF PATTERN-DIRECTED INFERENCE SYSTEMS
(From: Waterman, D. and Hayes-Roth, F. Pattern-Directed Inference Systems, 1978, Academic Press pp. 582-583.)

	Problem Recognition	Alternative Development	Information Acquisition & Evaluation	Alternative Evaluation & Selection	Feedback Monitoring
Utility Assessment Techniques			X	X	
Multi-Attribute Utility Analysis	X		X	X	X
Cost-Benefit Analysis			X	X	
Discounting Models			X	X	
Monte Carlo Methods			X		
Group Utility Aggregation			X	X	
Probability Elicitation			X		X
Bayesian Updating	X		X		X
Sensitivity Analysis	X		X		X
Group Probability Aggregation			X		
Subjective Expected Utility			X	X	X
Probabilistic Multi-Attribute Utility Analysis			X	X	X
Risk-Benefit Analysis			X	X	
Decision Tree Structuring		X	X	X	
Group Decision Analysis		X	X	X	
Partial Information Based Decision Analysis	X		X	X	X
Fuzzy Decision Analysis			X	X	X
Warfare Area Models	X		X	X	X
Lanchester Theory of Combat		X		X	
Game Theory				X	
Time Invariant Statistical Detection			X		X
Signal Detection	X		X		X
Search Modeling			X		
Simulation and War Gaming			X	X	
Scheduling			X	X	
Mathematical Programming				X	
Tactical Simulation	X	X	X	X	
Coverage Templates			X	X	
Time Distance Algorithms				X	X
Database Organization		X	X	X	
Man-Machine Communication	X			X	X
Message Processing	X		X		X
Clustering	X	X	X		
Classification	X			X	X
Information and Discrimination Measures			X	X	
Linear Discriminant Functions	X			X	
Problem Representation		X			
Problem Solving					
Learning Systems	X				X
Artificial Intelligence Inference System				X	
Planning Mechanism		X			X

FIGURE 5-2.
AIDING TECHNIQUE X FUNCTIONAL REQUIREMENT
RELEVANT MATRIX

figure of merit (0-10 for example), it was decided not to because, except in a few cases, there would not be a really firm basis for this assessment such as results of psychological experiments. Instead, a cross-mark was put in the boxes corresponding to a fairly significant relevance. This eliminates from further consideration the decision aiding techniques which might have only a marginal effect on a given function.

A decision-aiding technique will be called plausible for a given decision situation if it is relevant to at least one of the functional requirements which characterize the decision situation. Since a decision situation is associated to a set of functional requirements, it is easy to scan through the decision-aiding techniques which are relevant to these functional requirements using the matrix of Figure 5-2 and, consequently define those decision-aiding techniques which are plausible for this decision situation.

5.4 Decision Aid Characteristics

5.4.1 Overview. It was sought to define a set of descriptors which completely and uniquely define decision aids and yet are usable, i.e., whose dimensions are modest. As in the general case where designing a set of attributes is required, the principles highlighted by Keeney and Raiffa (1976) were followed. In this particular case the decision aid taxonomy is aimed at selection of decision aids particularly suited to a given decision situation. It was realized that the degree of appropriateness of a decision aid can be appreciated along two sets of dimensions: (1) the decision-aiding technique(s) embodied in the decision aid and (2) implementation-oriented characteristics. The influence of the second set of dimensions hopefully optimizes the performance by adapting the implementation of decision-aiding technique(s) to the requirements of the particular decision situation. Our taxonomy of decision aids was consequently based upon two sets of descriptors: (1) decision-aiding technique(s) utilized, and (2) implementation-oriented characteristics falling into two categories, namely features and costs.

5.4.2 <u>Decision-Aiding Techniques as Decision-Aid Characteristics</u>. The available decision-aiding techniques were listed in Table 5-1 and the way they bear on decision-making functions was portrayed in Figure 5-2. Similarly, decision-aiding techniques bring to bear on decision-task attributes their inherent particularities. For instance, it is obvious that Multi-Attribute Utility Analysis is very suitable for Multi-Attribute decision tasks. Similarly, a structuring aid such as Decision Tree Structuring is obviously very relevant for an ambiguous decision task as it provides a framework for decision makers to focus their attention on possible additional states of nature and alternative combinations.

For each decision-aiding technique the decision-task attributes which they contribute were identified. The results of this study are depicted in Figure 5-3, portrayed in the form of a relevance matrix. The entries of this matrix are based on expert judgements as well as relevant literature. These entries are the result of a first attempt to identify the relationships between decision-aiding techniques and decision-task attributes. Validation of these results can be pursued via a detailed analysis based on a larger sample of expert judgements. Note that some techniques are relevant to two modes of certain decision-task attributes. For instance, Discounting Models contribute to both individual and group decision tasks. A contrario, in certain cases, it is not clear if a decision-aiding technique bears at all on a particular decision-task attribute. For instance, it is unclear how Group Utility Aggregation relates to one-shot or repetitive decision tasks. Under such conditions, the corresponding two cases in the table of Figure 5-3 were left blank. A mark in a box means that the correponding decision-aiding technique is relevant to the corresponding decision-task attribute.

	SINGLE ATTRIBUTE	MULTI-ATTRIBUTE	INDIVIDUAL	GROUP	STATIC	DYNAMIC	ONE SHOT	REPETITIVE	CERTAINTY	RISK/UNCERTAINTY	WELL DEFINED	AMBIGUOUS	DECISION MAKING	DECISION EXECUTION	TIME CRITICAL	TIME RELAXED	SMALL PREMIUM/HIGH LOSS	NORMAL RANGE	TYPE 1	TYPE 2	TYPE 3
UTILITY ASSESSMENT TECHNIQUES	X				X		X	X	X		X		X			X		X		X	X
MULTI-ATTRIBUTE UTILITY ANALYSIS		X	X	X	X		X	X	X		X		X			X		X		X	X
COST-BENEFIT ANALYSIS	X	X	X	X	X		X		X	X	X		X			X		X		X	X
DISCOUNTING MODELS	X	X	X	X		X	X		X		X		X			X		X		X	X
MONTE CARLO METHODS	X	X	X	X	X	X	X		X	X	X		X			X	X	X	X	X	X
GROUP UTILITY AGGREGATION	X	X		X	X		X		X		X		X			X	X	X		X	X
PROBABILITY ELICITATION	X		X		X		X	X		X	X		X			X	X	X		X	X
BAYESIAN UPDATING	X		X		X	X	X	X		X	X		X		X	X	X	X		X	X
SENSITIVITY ANALYSIS	X	X	X	X	X		X		X	X	X		X			X	X	X		X	X
GROUP PROBABILITY AGGREGATION	X			X	X		X			X	X		X			X		X		X	X
SUBJECTIVE EXPECTED UTILITY	X	X	X		X		X	X		X	X		X			X		X		X	X
PROMA MULTI-ATTRIBUTE UTILITY ANALYSIS	X		X	X	X		X			X	X		X			X		X		X	X
RISK-BENEFIT ANALYSIS	X	X	X	X	X		X			X	X		X			X	X	X		X	X
DECISION TREE STRUCTURING	X	X	X	X	X		X		X	X	X	X	X			X	X	X	X		X
GROUP DECISION ANALYSIS	X	X		X	X		X			X	X		X			X		X		X	X
PARTIAL INFORMATION BASED DECISION ANALYSIS	X	X	X	X	X		X		X	X	X		X			X	X	X		X	X
FUZZY DECISION ANALYSIS	X	X	X	X	X		X			X	X	X	X			X		X		X	X
WARFARE AREA MODELS	X	X	X		X		X			X	X		X			X	X	X		X	X
LANCHESTER'S THEORY OF COMBAT	X	X	X		X		X		X	X	X		X			X		X		X	X
GAME THEORY	X	X	X	X	X	X	X	X		X	X		X			X	X	X		X	X
TIME INVARIANT STATISTICAL DETECTION	X	X	X		X		X	X		X	X	X	X			X	X	X		X	X
SIGNAL DETECTION		X	X			X		X		X	X	X	X		X		X	X	X		X
SEARCH MODELING		X	X	X		X		X		X	X	X	X		X	X	X	X	X	X	X
SIMULATION AND WAR GAMING	X	X	X		X		X			X	X		X			X		X		X	X
SCHEDULING	X	X	X		X		X		X		X		X			X		X		X	X
MATHEMATICAL PROGRAMMING	X	X	X		X		X		X		X		X			X		X		X	X
TACTICAL SIMULATION	X	X	X	X	X		X			X	X	X	X			X	X	X	X	X	X
COVERAGE TEMPLATES	X		X	X		X	X	X	X		X		X		X	X		X		X	X
TIME/DISTANCE ALGORITHMS		X	X		X		X		X		X		X			X		X		X	X
DATABASE ORGANIZATION	X	X	X	X	X	X	X	X			X			X		X		X	X	X	X
MAN-MACHINE COMMUNICATION	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X		X	X
MESSAGE PROCESSING	X	X	X	X	X	X	X	X	X	X	X		X		X	X		X		X	X
CLUSTERING	X	X	X		X		X	X	X	X	X		X			X		X		X	X
CLASSIFICATION	X	X	X		X	X	X	X	X	X	X		X		X	X		X		X	X
INFORMATION AND DISCRIMINATION MEASURES	X	X	X		X	X	X	X		X	X		X		X	X		X		X	X
LINEAR DISCRIMINANT FUNCTIONS	X	X	X		X	X	X	X	X	X	X		X		X	X		X		X	X
PROBLEM REPRESENTATION	X	X	X	X	X		X		X	X	X		X			X		X	X	X	X
PROBLEM SOLVING	X	X	X	X	X		X	X	X	X	X		X		X	X		X		X	X
LEARNING SYSTEMS	X	X	X	X	X		X	X	X	X	X		X		X	X		X	X	X	X
PATTERN-DIRECTED INFERENCE SYSTEMS	X	X	X	X	X		X	X		X	X		X			X		X		X	X
PLANNING MECHANISMS	X	X	X	X	X		X		X	X	X		X			X		X		X	X

FIGURE 5-3.
DECISION-AIDING TECHNIQUE X DECISION-TASK
ATTRIBUTE RELEVANCE MATRIX

5.4.3 Decision-Aid Features. The first set of implementation-oriented characteristics of decision aids that we called features relates also to decision-task attributes. While decision-aiding techniques relate to both functional requirements and attributes of a given decision situation, the features relate only to attributes. The features whose list appears in Table 5-5 are generally defined as pecularities related to implementation. They are:

(1) Interaction which is the capability of a decision aid to accommodate man/machine interaction according to the relevant Human Factors principles.

(2) Real-time which reflects a quasi instantaneous response time for the decision aid.

(3) Flexible which is the ability of the decision aid to adapt to a new problem or to the incorporation of additional elements.

(4) Multi-User Mode which is the ability of the decision aid to accommodate inputs from more than one person.

(5) Alert which is the capability of the decision aid to alert the user at certain key moments by audio or visual signal.

(6) Reasonableness Check which measures the ability of the aid to check for unreasonable values, e.g., falling out of the usual boundaries.

The features defined above are implementation oriented because no matter what decision-aiding technique it employs, a decision aid may or may not possess them. They hinge, however, on decision-task attributes as depicted in Figure 5-4 in which a mark in a box means that the corresponding feature is important to have in a decision situation characterized by the corresponding attribute.

TABLE 5-5
DECISION AID FEATURES

. INTERACTIVE

. REAL-TIME

. FLEXIBLE

. MULTI-USER MODE

. ALERT

. REASONABLENESS CHECK

	Interactive	Real-Time	Flexible	Multi-User Mode	Alert Capability	Reasonableness Check
Single attribute						
Multi-attribute			X			
Individual						
Group				X		
Static						
Dynamic	X		X			
One shot						
Repetitive	X				X	
Certainty						
Risk/Uncertainty					X	
Well defined						
Ambiguous	X		X			X
Decision making						
Decision execution						
Time critical		X			X	
Time relaxed						
Small proba/high loss	X					X
Normal range						
Type 1			X			
Type 2						
Type 3						

FIGURE 5-4.
DECISION-TASK ATTRIBUTE BY DECISION-AID
FEATURE RELEVANCE MATRIX

5.4.4 Decision-Aid Costs. The second implementation-oriented set of descriptors is quantitative in nature and aim at placing a cost figure on decision aids. As depicted in Figure 5-5, system costs fall into two broad categories: the first one, Dollar Costs reflects how much money it takes to make the aid available. The second category, or user costs is more subtle. While ease of use and user's acceptance obviously hinge on training requirements, i.e., carry a Dollar Cost, there is more to it than just dollars. If the aid is hard to use or if it is "suspect", e.g., if users think that it "replaces" their judgement, then it will seldomly or reluctantly be used. These detrimented effects will be minimized during the design/selection phase by using well-established principles or man/machine dialogue and Human Factors in general. Nevertheless, these user costs must be assessed and taken into account.

When figuring out costs, there is a fundamental distinction between an already existing system versus a new one to be designed and implemented. It is relatively easy to estimate the cost of acquisition of an already existing system. In this case, questions must be answered such as "Is it a stand-alone system?" "Is it compatible with the present installations?" "Is the storage available sufficient for my purpose or do I need additional storage?" "Is there a need for a tape-drive and how much would it cost?" Costing out a new system is much harder and to do so requires a careful study. For a c... er-based aid, for example, the following steps should be followed: Firs.., a feasibility assessment must be performed, i.e., the computational and memory requirements which are of the type Cn, An^2, 2^n, etc. must be reviewed in terms of (1) the maximum expected value of n (which could be, for instance, the number of attributes of the expected number of occurrences of an information element) and (2) what the technology will provide when the system is to be procured. A technology forecast is presented in Figure 5-6. The rationale behind considerations of this sort is that in the last twenty years the electronics industry

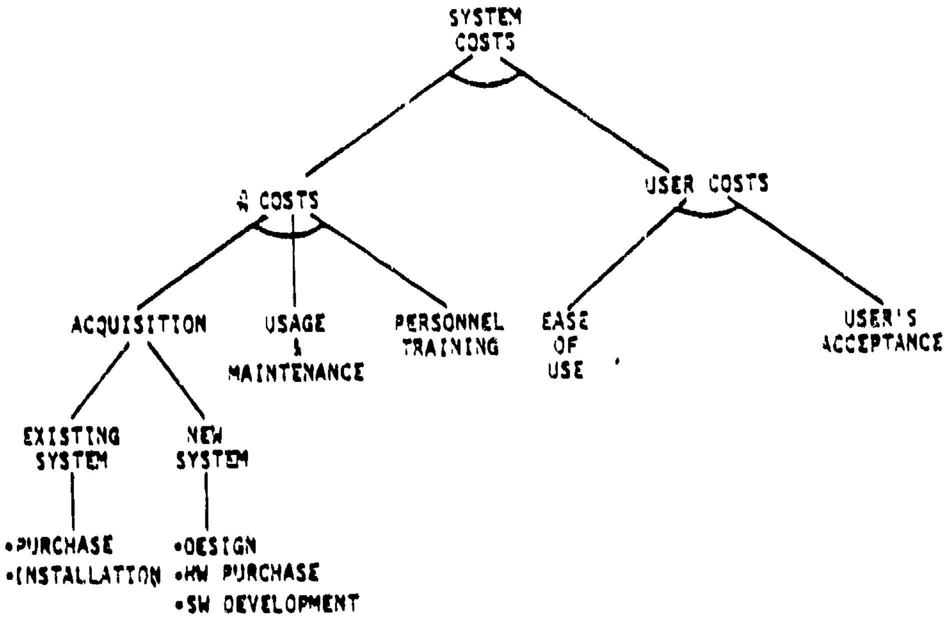
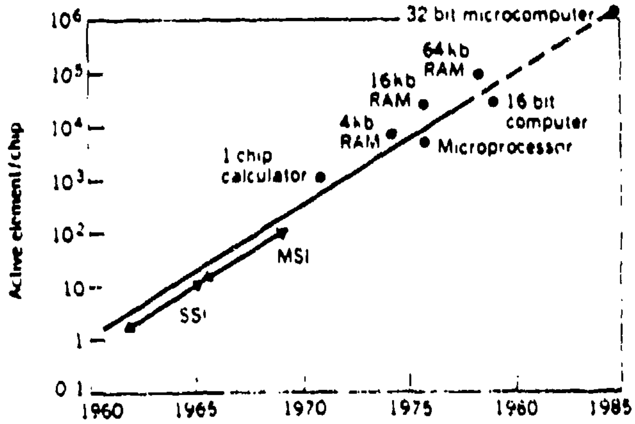


FIGURE 5-5
DECISION-AID COSTS

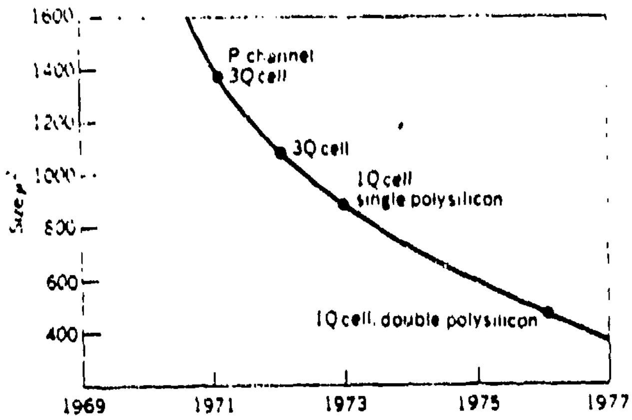


1. IC Complexity: past, present and future.

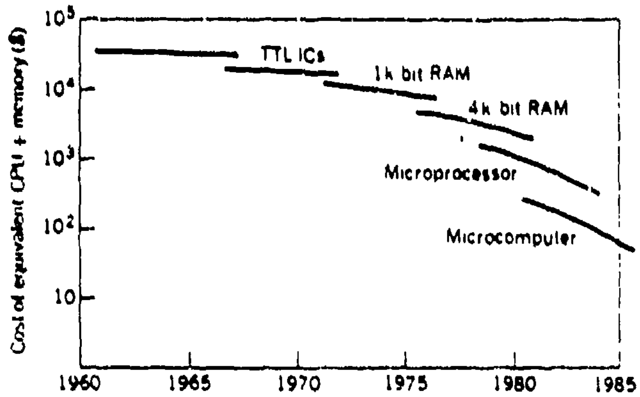
Parameter	1976 (NMOS process)	1980 (HMOS II process)	1985 (SBMOS/ DIMOS processes)*
Speed, ns (internal gate)	6	2	1
Power dissipation, mW (per gate)	3	0.5	0.25
Speed-power product, pJ	18	1.0	0.25
Power dissipation per package, watts	1	1.5	5

* Schottky barrier MOS/dielectric isolation MOS

2. Comparative IC performance data



3. Evolution of RAM cell size over the 1969-1977 period.



4. Cost of computing power: forecasted evolution until 1985.

FIGURE 5-6.
TECHNOLOGY FORECASTS
(Source: Queyssac, D. "Projecting VLSI's Impact on Microprocessors," Spectrum, 1979, 16(5):38-41).

has shown a steady progress by doubling chip complexity about every year, from one gate per chip in 1960 to 100,000 gates around 1978. Conservative availability for the mid 1980's are:

(1) 1 million bit IC RAM for main memory.
(2) 4 million bit serial access bubble memory devices for secondary memory.
(3) 32 bit microprocessor with 1 million bits of internal memory and a speed of 5-10 MIPS.

As a last effort toward costing out the new system, estimates must be made of (1) operating system requirements and (2) language requirements. Finally, an estimate for the expected level of efforts in man-years must be provided.

6. MATCHING PRINCIPLES

6.1 Overview

The principles presiding over the matching of decision situations with decision-aiding techniques or decision aids are fairly simple, and all the ingredients required for this purpose have been previously defined. They fall into three categories:

(1) Decision situation characteristics consisting of (a) a set of functional requirements (i.e., decision-making functions required for performance of the decision task and not afforded by the decision maker who performs it) and (b) a set of decision-task attributes.

(2) Decision aid characteristics namely, a set of decision-aiding techniques and a set of decision set features.

(3) Three relevance matrices namely, decision-making function x decision-aiding technique, decision-task attribute x decision-aiding technique and decision-task attribute x decision-aid features.

The three relevance matrices constitute the backbone of the methodology and allow definition, in a very simple manner, of two scores for any decision situation/decision aid couple. First, an aiding score which reflects how well a decision aid fulfills the requirements associated to a decision situation is computed on the basis of the technique used only. Second, a suitability score is computed on the basis of the decision-aid features and reflects how well a decision aid matches the specific decision-task attributes at hand. While the aiding score is technique-oriented, the suitability score is implementation-oriented. The principles underlying the computation of these two scores are portrayed in Figure 6-1 and the specific modes of computation are described in the next sections. Finally, an example of actual computation is provided, thus illustrating the methodology.

6.2 Aiding Score

6.2.1 Overview. The aiding score is an aggregate of two partial scores respectively named plausibility degree and compatibility degree. While the plausibility degree relates the decision aid or decision-aiding technique to functional requirements, the compatibility degree relates the decision aid to decision-task attributes. The aiding score is obtained by multiplication of the plausibility degree by the compatibility degree so as to ensure that if either total implausibility (plausibility degree equal to zero) or total incompatibility (compatibility degree equal to zero) is present the resulting aiding score is zero.

6.2.2 Plausibility Degree. Using the functional requirement by decision aiding technique relevance matrix, it is possible to define a degree of plausibility for a particular decision-aiding technique in a particular decision situation by the ratio: (number of functions relevant to the decision-aiding and required by the decision situation)/(total number of functional requirements associated to the decision situation). This ratio is a number between 0 and 1. To illustrate its computation, consider a decision situation which requires the functions "alternative development" and "alternative generation and selection." The degree of plausibility of "decision tree structuring" will be 1 while that of "problem representation" will be 1/2 and that of "message processing" will be 0 (see Figure 5-2). Similarly, a plausibility degree can be defined for decision aids. If a decision aid uses only one decision-

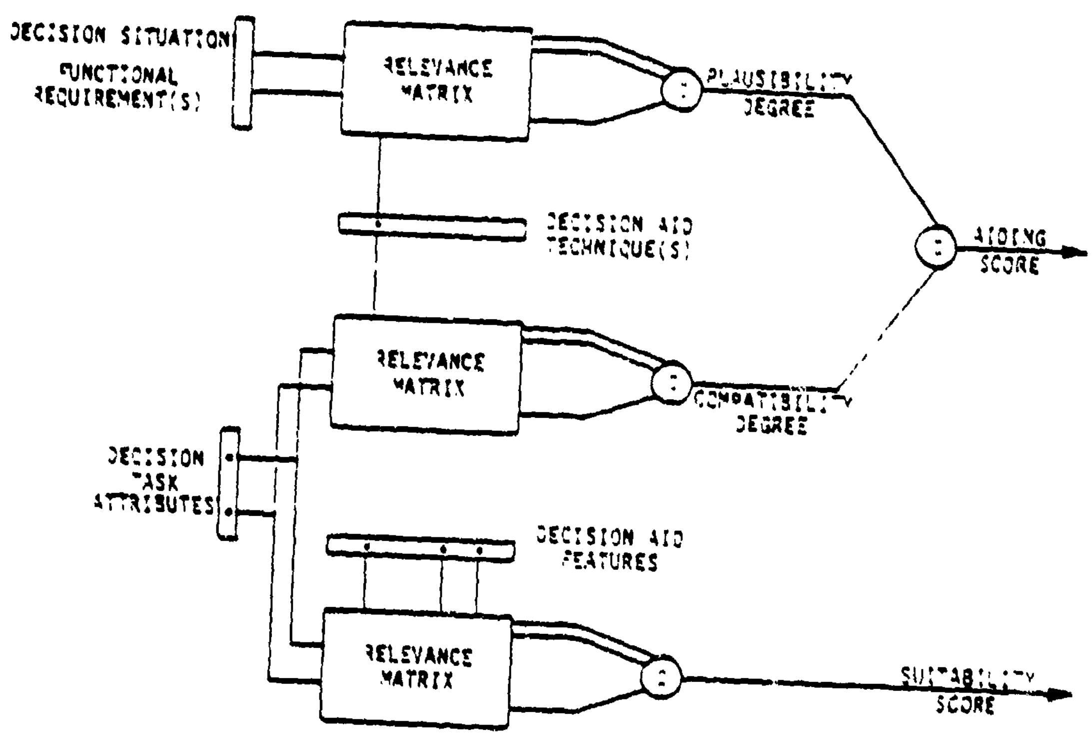


FIGURE 6-1
COMPUTATION SCHEME FOR DECISION SITUATION/DECISION AID SCORES

aiding technique, its plausibility degree coincides with that of the decision-aiding technique involved. If a decision aid utilizes more that one decision-aiding technique, its plausibility degree for a given decision situation will be the proportion of functional requirements "covered" by the union of the decision-aiding techniques embodied in the decision aid.

6.2.3 Compatibility Degree. Using the decision-task attribute by decision-aiding technique relevance matrix, we define the degree of compatibility of a decision-aiding technique in a particular decision situation by the ratio: (number of decision-task attributes associated with the decision situation which are "covered" by the decision-aiding technique)/(total number of decision-task attributes associated with the decision situation). Note that the denominator of the previous ratio is always 10, as the number of attributes associated with any decision task is 10.

As in the computation of the plausibility degree, the computation of the compatibility degree for a decision aid is performed by finding out the decision-task attributes which are covered by the union of the decision-aiding techniques the decision aid utilizes. For example, in a multi-attribute decision situation, Utility Assessment Techniques scores 0 for the first decision-task attribute, while a decision aid which uses both Utility Assessment Techniques and MAU Analysis would score one for the same attribute.

Note that some variations could be thought of; for instance, one might decide that all decision-task attributes are not equally important and assign importance weights to them. The above computation would then be modified and a match for given attribute would not necessarily be weighed by 1/10 but by some other number.

6.3 Suitability Score

The suitability score is obtained in a manner similar to the manner in which both plausibility and compatibility degrees are computed. Using the decision-task attribute by decision-aid feature relevance matrix, it is possible to associate to the decision situation at hand a set, possibly empty, of decision-aid features which are required for effective implementation. If this set is not empty, the decision-aid suitability score will be defined by the ratio: (number of required decision-aid features afforded)/(number of decision-aid features required). If the set of required decision-aid features is empty the suitability score will be set to one.

6.4 Selecting a Decision Aid

The first step toward selecting a decision aid for a particular decision situation is to define a measure of decision-aiding effectiveness afforded by the decision aid. Such a measure is provided by (for example) the product of the aiding and suitability scores. Using the resulting score and figuring out the costs associated to the decision aid will yield, by mere division, a measure of cost effectiveness for each decision aid. Note that this measure can be defined with a slight alteration for decision-aiding techniques. In the case of a decision-aiding technique which is not yet incorporated in an actual system, the suitability score is undefined (unless the set of required decision-aid features is empty). It is possible to maximize this suitability score by providing, at the implementation phase, all or part of the required features but it will be costly. Consequently, all implementation modes should be examined, i.e., no required features provided, one required feature provided, etc... A cost-effectiveness figure can be computed for the various modes and the modes which have the highest cost effectiveness will be retained and compared against the other plausible decision aids of decision-aiding techniques.

Costs, however, need not be directly incorporated with the effectiveness score yielding a single figure of merit. It is possible that a certain budget is available and one wants to optimize aiding scores within the budget constraints. In such a case, an aid slightly more costly than another might be selected if it provides an advantage in score and still remains within budget constraints.

6.5 Example of Application

In order to explicate the matching principles highlighted in the previous paragraphs, an example is treated next. Consider decision task "Designate Landing Areas" which was described in Section 3.5. The attributes and functional requirements for this task are described in Figure 6-2. It is assumed that this decision task is performed by a decision maker who does not provide the decision-making functions required, thus leaving the functional requirements of the decision situation identical to those of the decision task. On the other hand, consider decision aid OPINT (Selvidge, 1976) which is depicted in Figure 6-3. It is designed to compute the aiding score and the suitability score for OPINT as it relates to "Designate Landing Areas."

Figure 6-2 summarizes the attributes and functional requirements which characterize decision task "Designate Landing Areas." In addition, it shows how the attribute vector and the functional requirement vector are constructed based on the attributes and functional requirements associated with the decision task. Similarly, Figure 6-3 depicts how decision aid OPINT can be schematically represented. Using the information contained in Figures 6-2 and 6-3, the plausibility degree and the compatibility degree can be easily computed. First, the plausibility degree is obtained by matching the required functions with the functions afforded by the decision aid. Only alternative evaluation produces a match resulting in

ATTRIBUTES

MA
Individual
Static
One Shot
Uncertainty
Well Defined
Decision Making
Time Relaxed
Normal Panges
Type 3

SA	MA	I	G	S	D	O.S.	R	C	U	WD	A	DM	DE	TC	TR	SPHL	NR	1	2	3
0	1	1	0	1	0	1	0	0	1	1	0	1	0	0	1	0	1	0	0	1

FUNCTIONAL REQUIREMENTS

Alternative Development
Alternative Evaluation & Selection

Pb. Rec.	Alt. Dev.	Info. Acq.	Alt. Ev.	Feed. Mon.
0	1	0	1	0

Legend:

SA	= Single Attribute	U	= Uncertainty	1	= Type 1
MA	= Multi Attribute	WD	= Well Defined	2	= Type 2
I	= Individual	A	= Ambiguous	3	= Type 3
G	= Group	DM	= Decision Making	Pb. Rec.	= Problem Recognition
S	= Static	DE	= Decision Execution	Alt. Dev.	= Alternative Development
D	= Dynamic	TC	= Time Critical	Info. Acq.	= Information Acquisition
O.S.	= One Shot	TR	= Time Relaxed	Alt. Ev.	= Alternative Evaluation and Selection
R	= Repetive	SPH	= Small Probability/ High Loss	Feed. Mon.	= Feedback Monitoring
C	= Certainty	NR	= Normal Range		

FIGURE 6-2
SCHEMATIC REPRESENTATION OF DECISION TASK
DESIGNATE LANDING AREAS

Decision-Aiding Techniques	Probability Recognition	Alternative Development	Information Acquisition	Alternative Evaluation	Feedback Monitoring
Probability Elicitation			X		X
Bayesian Updating	X		X		X
MAUM	X		X	X	X
SEU			X	X	X
Sensitivity Analysis	X		X	X	X
OPINT	1	0	1	1	1

	SA	MA	I	G	S	D	OS	R	C	U	MC	A	DM	DE	TC	TR	SPHE	MR	1	2	3
Probability Elicitation	X		X		X		X	X		X	X		X			X	X	X		X	X
Bayesian Updating	X		X		X	X	X	X		X	X		X		X	X	X	X		X	X
MAUM		X	X	X	X		X	X	X		X		X			X		X		X	X
SEU	X	X	X		X		X	X		X	X		X			X		X		X	X
Sensitivity Analysis	X	X	X	X	X		X		X	X	X		X			X	X	X		X	X
OPINT	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	1

Features	Interactive	Real Time	Flexible	Multi User	Alert	Reasonableness Check
OPINT	1	0	1	0	0	0

Legend: See Figure 6-2

FIGURE 6-3.
SCHEMATIC REPRESENTATION OF DECISION AID OPINT

a plausibility degree of 1/2. The compatibility degree obtained by matching decision-task attributes with decision-aiding techniques is equal to 1 since, as can be seen in Figures 6-2 and 6-3, all the ones of the decision-task attribute vector are covered by ones of the decision-aid attribute vector. Using Figure 5-4 and matching against decision-task attributes, we see that the desired decision-aid features are (1) flexible and (2) alert capability resulting in a suitability score of 1/2 since the only desired feature afforded by the decision aid is (1). The aiding score is consequently 1/2 and the suitability score is also 1/2.

To figure out costs, the tree of Figure 5-5 will be used. The acquisition cost consists of the purchase cost and the installation cost. Since OPINT is a stand-alone software package running on IBM 5100 or 5110, the purchase cost is equal to the fee charged by the developer plus the cost of acquisition of an IBM 5110 (the 5100 has been discontinued) if this machine is not already available in the organization contemplating the acquisition of OPINT. The cost of usage and maintenance is that of the machine supporting the system and should be estimated in view of the other possible services the machine can render (the cost of purchase should be decreased if the machine is to serve other purposes other than supporting OPINT). The cost of training personnel is more related, in this case, to the decision-aiding techniques used, i.e., equal to the cost of training users in Decision Analysis. The user costs, namely ease of use and user's acceptance of course, hinge on the amount of training required, as mentioned earlier, but they are viewed here as measures of attitude and can be assessed via interviews of people who have already been exposed to OPINT. Once this assessment of dollar costs and user costs has been performed, a simple figure can be obtained by aggregation, using weights depending on the organization value system. This figure of merit can then be used to assess the cost effectiveness of OPINT and serve as a basis for comparison with other decision aids.

7. CONCLUSIONS

Since numerous comments have been made and partial conclusions presented in the text, only conclusions of a general nature are drawn here. The first main conclusion is that it is possible to analytically characterize MAB decision tasks in a meaningful way. A database was created which contains all identified MAB decision tasks with their respective information requirements, functional requirements and attributes. This database is of interest in its own right as it can be used for the purpose of detailed description. Along these lines an attempt was made to characterize high-level military functions such as "preliminary planning" in terms of decision-making attributes. However, since each function contains a large number of decision tasks, it is difficult to summarize them. The solution adopted was to characterize each function by these attributes which have a value approximately constant within the function. This provided high-level characterization of the MAB decision-making environment which is very useful in identifying general requirements for decision aiding.

The level of detail provided in the decision task taxonomy is sufficient for this taxonomy to be one of the cornerstones of a methodology allowing one to perform fine-grained discrimination between decision aids. Another cornerstone of this methodology is a decision maker taxonomy. It was not possible, however, to analytically characterize MAB decision makers in terms meaningful from a military standpoint so that they could be related to decision-task functional requirements. The second main conclusion was consequently that, since decision aids cannot be tailored to individual requirements within the MAB environment, they should be adaptive so as to minimize costs of replacement and training requirements when changes of personnel occur.

A decision aid taxonomy was then established based upon the decision-task dimensions identified for the decision task taxonomy. Two sets of decision-aid dimensions relating decision-task characteristics to decision aids were built and a set of matching principles established. These matching principles constitute a methodology allowing one to compute, for each decision aid, a degree of merit with respect to a given decision situation. After the costs associated with the purchase or design and development of the decision aid have been assessed, a cost-merit measure can be computed. The viability of the methodology was demonstrated by applying it to an example. The third main conclusion is, therefore, that it is possible to define a viable methodology to select a decision aid for a particular decision situation within the MAB environment. It should be clear, however, that the cost-merit measure of a decision aid with respect to a given decision situation (sometimes called cost-effectiveness measure in the text to remind its analogy with a general cost-effectiveness measure) is only a priori measure. To assess how effective a decision aid will be requires formal evaluation of the particular decision aid selected.

8. REFERENCES

Anderson, D.L. and Anderson, D.F. "Theories of Decision Making: An Annotated Bibliography," MIT, Alfred P. Sloan School of Management, 1976.

Ben-Bassat, M., Carlson, R.D., Puri, V., Lipnick, E., Portigal, L.D. and Weil, M.H. "Pattern-Based Interactive Diagnosis of Multiple Disorders: The MEDAS System," IEEE Transactions on Pattern Analysis and Machine Intelligence, 1979, (to be published).

Brown, R.V. and Ulvila, J.W. "Selecting Analytic Approaches for Decision Situations," DDI, 1977, report TR-77-7-25.

Buchanan, B., Sutherland, G. and Feigenbaum E. "Heuristic DENDRAL: A Program for Generating Explanatory Hypotheses in Organic Chemistry," in Machine Intelligence 4, 1969, Americal Elsevier, New York.

Buck, J. and Hancock, W. "Manual Optimization of Ill-Structured Problems," Int. J. Man-Machine Studies, 1978, 10:95-111.

Cockrell, J. "Evaluation of Four Target - Identification Training Techniques," ARI Technical Paper 301, 1978.

Duda, R. and Hart, P. Pattern Classification and Scene Analysis, New York, Wiley & Sons, 1973.

Duda, R., Hart, P., Nilsson, J., Reboh, R., Slocum J. and Sutherland, G. "Development of a Computer-Based Consultant for Mineral Exploration," SRI, 1977, Projects 5821 & 6415.

Edwards, W., Phillips, L., Hays, W. and Goodman, B. "Probabilistic Information Processing Systems: Design and Evaluation," IEEE Trans. on Systems, Science and Cybernetics, 1968, 4(3):248-265.

Haywood, O.G. "Military Decision and Game Theory," ORSA, 1954, 2(4):365-385.

Jacob, J.P. "Potential of Graphics to Enhance Decision Analysis," Second Lawrence Symposium on Systems and Decision Sciences, Oct. 3-4, 1978, Berkeley.

Keeney, R. and Raiffa, H. Decision Analysis with Multiple Conflicting Objectives, Preferences and Value Trade-Offs, 1975, Wiley, New York.

Koelln, K. "A Utility Model for Information Used in Tactical Decision Making and Planning by Maring Officers," M.S. Thesis, San Diego State University, Spring, 1976 (unpublished).

Leal, A., Levin, S., Johnston, S., Agmon, M. and Weltman, G. "An Interactive Computer Aid System for Group Decision Making," Perceptronics, 1978, PQTR-1046-78-2.

Lucas, G., and Ruff, J. "An Investigation of Operational Decision Aids," SPC, Log No. 77-3516, 1977.

MacCrimmon, K.R. and Taylor, R.N. "Decision-Making and Problem Solving," in Handbook of Industrial and Organizational Psychology, Dunnet (Ed.), 1976, Rand-NcNally.

Miller, A., Merkhofer, M., Howard, R., Matheson, J. and Rice, T. "Development of Automated Aids for Decision Analysis," 1976, Stanford Research Institude, Final Report, project 3309.

Payne, J., Miller, A. and Rowney, J. "The Naval Task Force Decision Environment, 1974, Stanford Research Institute Report.

Pople, H., Myers, J. and Miller, R. "DIALOG: A Model of Diagnostic Logic for Internal Medicine," Proceedings 4th INCAI, pp. 848-855.

Samet, M.G. "Quantitative Interpretation of Two Qualitative Scales Used to Rate Military Intelligence," Human Factors, 1976, 17(2):192-202.

Selvidge, J. "Rapid Screening of Decision Options," DDI, 1976, Report TR-76-12.

Shaket, E., Ben-Bassat, M., Madni, A. and Leal, A. "Applications of Adaptive Programming Technology (APT) to Command Group Training and Performance Improvement," Perceptronics PFTR-1055-78-12, 1978.

Shortliffe, E. MYCIN, Computer Based Medical Consultations, 1976, Americal Elsevier, New York.

Sinaiko, H. "Operational Decision Aids: A Program of Applied Research for Naval Command and Control Systems," Smithsonian Institute, 1977, Technical Report No. 5.

Smith, P. "Computer Aided Ship Tracking," IEEE Trans. on Systems, Man and Cybernetics, 1979, 9(1):58-62.

Taylor, R. and Dunnette, M. "Relative Contribution of Decision-Maker Attributes to Decision Process," Organizational Behavior and Human Performance, 1974, 12:286-298.

Walsh and Schechterman "Experimental Investigation of the Usefulness of Operator Aided Optimization in a Simulated Tactical Decision Aiding Task," ISC, 1978, Report 215-4.

Winston, P. Artificial Intelligence, 1977, Addison-Wesley, Reading (Mass.).

APPENDIX A
INFORMATION REQUIREMENT ATTRIBUTES

APPENDIX A

INFORMATION REQUIREMENT ATTRIBUTES

This appendix presents a set of attributes used in the project to characterize information requirements for different decision tasks. Each decision task can be considered as a black box which receives information and generates a decision solution. The information requirement attributes, in this case, provide a sufficient framework for defining the input characteristics.

Type. This attribute indicates the type of information, i.e., the tactical information class to which the information belongs. There needs to be a taxonomy of decision types (e.g., that of Koelln, 1976).

Size. Tactical information is generally in the form of messages whose size can be determined and expressed in number of characters for example.

Priority. Priority expresses the importance of the element of information. The message header generally contains a priority label.

Accuracy. Accuracy of an information element is generally judged by comparison with other elements of information. If the message content correlates well with other elements of information judged accurate then the corresponding information element will be classified as accurate.

Reliability. Reliability of an information element relates to its source and it is actually the source of the message and not the message content itself which is rated.

Specificity. This attribute describes how summarized or detailed is the information. This attribute may be used to describe a message that was complete or incomplete.

Familiarity. This attribute can be defined as the number of times a user has seen a message of similar type. It expresses the degree of ease with which the information can be handled by the user.

Age. The message header lists the time of origination of the message. The age can therefore be easily computed.

Value. The value of a message varies from one user to another and can be, for example, defined as a linear combination of the attributes above, defined with weights depending on individual users.

Cost. The cost of an information can be defined as the loss incurred by the user who does not receive it. Costs can be easily assessed for information tupes at various phases of the operation.

APPENDIX B

DECISION-TASK ATTRIBUTES

APPENDIX B

DECISION TASK ATTRIBUTES

The decision-task attributes used in this project to characterize MAB decision tasks are described in this appendix. The definition of each attribute is summarized in a general definition specifying the attribute discriminantly. This definition is then amplified through examples accompanying more detailed descriptions of the attribute. A set of rules for the classification of decision tasks according to each attribute as well as potential pitfalls and limitations for this classification are given. The impact of each attribute on other decision elements such as risk attitude and outcome estimation is defined and prerequisite functions for completing a decision task with each specific attribute is described.

SINGLE-ATTRIBUTE DECISION MAKING

General Definition. A decision where the action taken and the state of the world in combination determine the outcome (payoff) where the outcome (payoff) is a single value dimension (attribute).

Amplification. A decision maker is frequently asked to choose between courses of action whose probable consequences are characterized by a single value attribute (for example, deciding on the amount of ammunition for a particular type of weapon to take on a mission). The outcomes, depending on the amount taken and the number of occasions for use encountered during the mission (state of nature) will determine the single attributed outcome: adequacy of supply on hand. Adequacy of supply is a single outcome ranging from some numerical shortage to a numerical surplus.

Rules. Identify the decision outcome for each action/state of the world. The outcome may be either estimated directly by experts, predicted by modeling, or predicted by experimental evidence. Each outcome may be either wholly subjective, subjective estimates on an objective scale, or objective measurements on an objective scale.

Pitfalls and Limitations. The most important pitfall is the representation of an outcome by a single point estimate when the outcome itself may have a range or may be a probability density function.

Interactions With Other Decision Elements. No major interactions.

Prerequisites. There must be a method or mechanism that permits outcome estimation either by training people to estimate outcomes or by automatic projection.

MULTI-ATTRIBUTE DECISION MAKING

General Definition. A decision situation where the action taken and the state of the world in combination determines the outcome (payoff) where the outcome (payoff) involves multiple value dimensions (attributes).

Amplification. Decision makers frequently choose between courses of action whose probable consequences are each characterized by multiple value attributes. For example, the decision whether or not to satisfy a request for fire involves dimensions of value such as availability of adequate weaponry, possible interference with other fires, troop safety. In making a decision in such a situation, all such value-relevant factors must be identified for each alternative/state of nature.

Rules. Identify, for each action alternative/state of nature, the set of outcomes across all value dimensions. Outcomes may be either estimated directly by experts, predicted by modeling, or predicted by experimental evidence. Each outcome may be either wholly subjective, subjective estimate on an objective scale, or objective measurement on an objective scale. In addition, each value dimension carries an importance weight generally used in some fashion to perform trade-off analyses.

Pitfalls and Limitations. The most important pitfall is the representation of an outcome by a point estimate when in fact the outcome is a range or may itself be a probability density function.

Interactions With Other Decision Elements. No major interactions.

Prerequisites. There must be a method or mechanism for generating outcome estimates. This may involve training outcome estimation, providing standard lists of outcome estimation, and so on.

INDIVIDUAL DECISION MAKING

General Definition. A decision which is made by a single individual.

Amplification. Although more than one person may be involved in the process, the selection of the preferred alternative is the sole responsibility of one person. For example, the Commander's estimate of the situation takes as input staff estimates and recommendations. Still, the Commander's decision, which is a consequence of this analysis, is the Commander's sole responsibility, thus rendering the task individual.

Rules. Identify who is responsible for making the decision. In the case where more than one individual is involved in the decision-making process, identify what is the exact role of each person. If only one person performs the final decision while the others merely support the decision with advice or expert opinion, the decision is individual.

Pitfalls and Limitations. It is often difficult to distinguish between a group and an individual decision task. Sometimes a suggestion from an expert can become, after approval, the final decision. In such a case, it is hard to determine if the decision is an individual or a group decision.

Interactions With Other Decision Elements. The major interaction exists with the risk element. There is experimental evidence that there exists a risk shift between individuals and groups. Groups are actually less risk-avert than individuals. Similarly, groups have a tendency to be more conservative in their probability revisions than the individual taken separately.

Prerequisites. None.

GROUP DECISION MAKING

General Definition. A decision which is made by more than one person.

Amplification. A group is involved in the decision process and more than one person takes an active part in the decision. In other words, more than one person actually generate alternatives or perform a selection among alternatives. For example, in the task "Generate Friendly Courses of Action" which is part of the Operations Estimate, the commander and the G3 both cooperate in the alternative generation process and consequently the decision is a group decision. In the case of a decision which involves both alternative generation and alternative selection, if the selection is performed by a single individual and the generation of alternatives is performed by a group, the task should be decomposed into two subtasks. If this breakdown cannot be performed, the overall task should be classified as group.

Rules. Identify who is involved in the decision task and make sure that more than one individual perform all or part of the decision.

Pitfalls and Limitations. The most important pitfall is classifying the decision as group when only a fraction of the decision is performed by a group.

Interactions With Other Decision Elements. Except for the "risky shift" described in individual decision making, the decision type is important since there is experimental evidence than groups generate richer alternative sets.

Prerequisites. There ought to be a method to possibly resolve disagreements and inconsistencies among group members (Arrow theorem, delfi method, averaging, etc.).

STATIC DECISION MAKING

General Definition. A decision situation is static if the consequences of the decision specified through the outcome set are constant over time (i.e, not a function of time).

Amplification. Consider the time horizon over which the consequences of a decision unfold. If the consequences (outcome set) remain constant over that time horizon, the decision is static. This outcome set, with a correct representation, is required for properly structuring the decision. For example, in deciding about the rank order of the courses of action for a certain estimate of supportability the outcome set is "correct" or "erroneous" assessment. This set remains constant over the time horizon which is, in this example, the planning phase i.e., the period of time before D-Day.

Rules. Determine the pattern of decision consequences (outcome) over time and if the response pattern is constant, the situation is static and a point estimate may be used to represent the outcome. In essence, a "snapshot" of the consequence may be taken at any point in time to represent the outcome.

Pitfalls and Limitations. In some instances, there will be outcomes that are both static and dynamic (vary with time) and they must be identified and treated separately. Confusion can be minimized if the consequence magnitude is plotted over time to determine if magnitude is a function of time.

Interactions With Other Decision Elements. There is some interation with outcome estimation that follows from attribute (value dimension) specification. In some instances, dynamic patterns can be represented by static attributes by careful wording in identifying the static attribute. For example, peak response takes a characteristic of a dynamic response and represents it by a static attribute.

Prerequisites. An understanding of how the situation is defined as a function of time.

DYNAMIC DECISION MAKING

General Definition. A decision situation where the action taken produces consequences that vary as a function of time.

Amplification. Consider the time horizon over which the consequences of a decision unfold. If the consequences (outcome set) are not constant (i.e., display of pattern over the time horizon) the decision is dynamic. This has critical implications for outcome specification since the pattern cannot be captured by a single number. The outcome, in fact, may have a number of transient states and an eventual equilibrium, each state affecting the decision to be made in different ways. For example, in monitoring the requests for fire support during the operation the officer in charge must match the request with his assets while observing the environment. This situation is highly dynamic as the assets, (some on board ships) might be moving; the target too might be moving or if it is fixed, troops might be in its vincinity. Consequently, at each point of time a new decision problem must be solved. Care must be given to using the respective durations in trying to develop numbers to represent the decision outcomes, not just a single point estimate.

Rules. Determine the pattern of decision consequences (outcomes) over time and if the response pattern changes over time, the situation is dynamic and the entire response pattern and its characteristics must be considered in order to represent the outcome. Characteristics of response patterns such as peak and valley magnitudes, durations of peaks and valley, transients, ultimate steady state, time to reach steady state, and so on, must be considered.

Pitfalls and Limitations. In some instances the decision between static and dynamic will be confounded by the distinction between discrete and continuous decision making.

Interactions With Other Decision Elements. See comments under static decision making. In addition, dynamic consequences represented by static attributes tend to make single attribute decision making into multi-attribute decision making. Hence, dynamic outcomes may preclude single attribute decision making.

Prerequisites. An understanding of how behavior varies as a function of time, and ability to characterize components of patterns of behavior such as durations, peaks, periodicity, etc., are important prerequisites.

ONE-SHOT DECISION MAKING

General Definition. A decision which occurs once during the course of a mission and is functionally distinct from all other decisions in the mission.

Amplification. Mission decisions may be categorized into those that are repetitive -- occur repeatedly in a similar, if not identical form -- and those which are unique and experienced only once or only a few times. Typical examples of one-shot decisions are planning decisions and emergency responses. These may be single-stage or multi-stage in nature and generally require exhaustive planning in advance of the decision. The planning is necessary since in-task observations normally cannot be made of the possible actions and form and likelihood of the possible outcomes.

Rules. The key rule is that of distinctness from other decisions. The objectives, action, and outcome set must be sufficiently distinct from other decisions that training on those other decisions will not lead to adequate performance on the unique decision.

Pitfalls and Limitations. One-shot decisions may be subject to two problems: (1) A complete set of actions and outcomes may not be easily generated, since the decision typically cannot be observed repeatedly. Extensive analysis is necessary (i.e., aircraft stage responses, nuclear station fault analysis). Also, probabilities of outcomes must be generated analytically rather than observed. (2) If time permits, extensive analysis may be considered. The necessity of extensive analysis must be assessed baring in mind not only the frequency, but also the criticality of the decision task.

Interactions With Other Decision Elements. May require simulation or analysis.

Prerequisites. None.

REPETITIVE DECISION MAKING

General Definition. A situation which is repeatedly performed during a mission.

Amplification. A repetitive decision situation is performed again and again. Typical examples of such decisions are monitoring situations. In this instance, a decision maker monitors the situation and at each instant questions the need for action. The exact number of times the task is performed is not exactly known. The decision is actually of the continuous type, thus, implying that this number could be infinite.

Rules. Examine the decision process. If the number of times this process is repeated is very large or if the process is of continuous nature, the decision is repetitive.

Pitfalls and Limitations. See comments under one-shot decision making.

Interactions With Other Decision Elements. No major interaction.

Prerequisites. None

CERTAINTY DECISION MAKING

General Definition. A decision in which the state of the world which will obtain and the outcome for each course of action are known.

Amplification. The decision situation is not adversary i.e., the state of the world which will obtain is known and consequently does affect either the generation of alternatives or the selection of the best alternative. The decision generally consists of a trade-off analysis on the basis of one or more attribute dimensions. Typical examples in the environment under investigation are the detailed planning decisions which are of the resource allocation type, for instance, preparation of the landing plan. There it is just a matter of implementing the course of action chosen during the preliminary planning phase.

Rules. Find out if the state of nature which will obtain is known or if the decision requires to consider all the uncertainty elements.

Pitfalls and Limitations. Sometimes a risky situation is treated as a certainty situation while it is actually not. This is what is done under military doctrines based on intentions where the intelligence officer "guesses" what the enemy will do and subsequent decisions are based upon these premises.

Interactions With Other Decision Elements. No major interaction.

Prerequisites. There ought to be a way of ranking outcomes according to preference.

RISK DECISION MAKING

General Definition. A decision where the outcome associated with each alternative and each state of nature is known and there is uncertainty regarding which state of nature will obtain.

Amplification. Decisions under risk imply that the decision maker can deterministically identify each outcome when the alternative and the state of nature are specified. Probabilistic outcomes, when the state of nature is known, are not accounted for by decision analysis. An example of risk decision situation is the commander's estimate of the situation where the risk analysis is provided by the intelligence officer. Actually, the probabilities associated with the enemy courses of action can be estimated but this estimation is not required by the doctrine; it is only required that the enemy courses of action be ranked by decreasing order of probability of adoption. A decision under risk where the probabilities are not known is sometimes referred to as a decision under uncertainty. These latter situations are included in our definition of decision under risk as well because they require similar treatments.

Rules. Identify if it is known in advance which state of the world obtains.

Pitfalls and Limitations. The major pitfall is that risky decisions with known probabilities are not distinguished from risky decisions with unknown probabilities.

Interactions With Other Decision Elements. The major interaction is with the criteria adopted for alternative selection (expected utility, minimax, maximin, etc.).

Prerequisites. There should be a mechanism allowing to handle situations where probabilities are partially known, for instance, they are constrained to be in certain intervals or to satisfy certain inequalities.

ABSTRACT DECISION MAKING

General Definition. A situation which is defined in general terms.

Amplification. If a task is defined in terms which are general i.e., not specific to the environment under study, general conclusions available for the particular task can be applied. An example of such a task could be "generate alternatives". Although no task defined in abstract terms was found in this study, this definition was added for the purpose of completeness.

Rules. Identify if the task definition refers specifically to the environment. If it does not, the task is abstract.

Pitfalls and Limitations. Some tasks are defined in abstract terms but must be classified as concrete. For instance, the task "generate friendly courses of action" is very close to the abstract task "generate alternatives", and still should be classified as concrete.

Interactions With Other Decision Elements. No major interaction.

Prerequisites. None.

WELL DEFINED DECISION MAKING

General Definition. A decision situation where the action alternatives, states of nature, and outcome set are completely describable, well defined, well understood in advance of the actual decision making situation.

Amplification. A key to any decision situation is problem structuring. The prerequisites for structuring are: (1) knowledge of the complete set of action alternatives to be considered, and (2) knowledge of all likely states of nature that will be involved in the situation. If these prerequisites are met, the situation is well defined and can easily be structured. For example, in determining the target classification and priority, the alternatives are very clear and so are the outcomes as a target may be partially destroyed, anihilated, etc... In this example, the decision situation is well defined.

Rules. There are two possible mechanisms used to present the detailed structure of well-defined decision making situations: (2) the payoff (or loss) table, and (2) the decision tree. The general procedure is to express the decision alternatives and, for each alternative, list consequences under each state of nature. In one case, the result is in matrix form, in the other the result is in tree diagram form. If there are a sequence of decisions, a decision tree is usually best for structuring.

Pitfalls and Limitations. A tree or matrix summarizing a decision situation forces closure in a specific decision situation. There is a tendency to view the decision in terms of the tree or matrix only, rather than realizing that the actual decision may involve more than what is just shown in the structure. That is, the closure may be in error with a major element of the decision omitted.

Interactions With Other Decision Elements. The outcomes to be displayed are either single or multiple and are generated as indicated earlier. Also, there may not be enough time to create a large structure.

Prerequisites. A tree or matrix structure should be developed or provided. If developed, the basic material for constructing such a structure must be provided. The set of possible action alternatives should be provided with the outcomes for each prespecified alternative state of nature. The set of action alternatives should be mutually exclusive and exhaustive.

AMBIGUOUS DECISION MAKING

General Definition. A decision situation where the action alternatives, states of nature, and outcome set is either ill defined or not completely understood prior to or during the actual decision making situation.

Amplification. The prerequisites for structuring any decision situation as indicated previously are (1) knowledge of the complete set of possible action alternatives to be considered in the decision situation and (2) knowledge of all likely states of nature that will be involved in the situation. In ambiguous situations, either one or both of these preconditions for well defined decision making structuring fail. There are two distinct kinds of failure: (1) the set of states of nature or the set of possible action alternatives is so large that for practical purposes it cannot be represented in matrices or tree diagrams, (2) the set of states of nature or the set of possible action alternatives cannot be anticipated completely in advance of the actual decision situation. For example, very early in the planning phase only very little is known about the enemy situation. Yet certain basic decisions have to be made in this environment for which the general set of alternatives and states of nature are known but the complete set are not.

Rules. As in the case of well-defined situations, structure what is known in matrices or decision trees and specify unknowns where appropriate. In addition, indicate that part of the structuring must occur at the time of the actual decision. The concept of closure must be firmly addressed as well as sufficiency of the alternative set. Sensitivity analysis should be conducted to determine decision sensitivity to structure.

Pitfalls and Limitations. In particular, any structure provided tends to take on more value than is warranted. Preliminary structuring may preclude additional structuring as an expedience. There are no complete rules for specifying when all the likely and relevant states of nature have been specified.

Interactions With Other Decision Elements. The outcomes to be displayed are either single or multiple and are generated as indicated earlier. Also, there may not be enough time to create a large structure.

Prerequisites. A tree or matrix should be developed or provided. Particular attention should be given to providing methods for forcing consideration of additional states of nature and alternative combinations. The set of alternatives and states of nature provided, while not exhaustive, must be mutually exclusive.

TIME CRITICAL DECISION MAKING

General Definition. A decision situation where the decision maker has insufficient time to completely structure the decision in terms of number of attributes, alternatives, states of nature, and outcomes as well as alternative selection. In summary there are time constraints and the greater the constraints, the greater the pressure.

Amplification. In those situations where fast moving events preclude adequate consideration of structuring a decision and selecting an alternative, there is time pressured decision making. For example, when an unforeseen situation occurs, e.g., a company is all of a sudden under intense enemy fire, there is very little time to reflect.

Rules. There are only rules of thumb under time pressure. The most obvious one is "Don't take longer than the time available to structure the decision and select an action." If this happens, the decision is out of the decision maker's control. The general rule is to spend time on structuring the decision at the expense of a hasty action selection. In most cases, the wrong decision following a correct structuring is easier to recover from than the correct decision on the wrong problem. Also, try to focus on the major decision elements immediately, foregoing a close look at the secondary considerations.

Pitfalls and Limitations. The idea of the optimal decision under time pressure is illusory. The best that one can hope for in many instances is to avoid making a "big" mistake by utilizing the knowledge provided in previous trainings.

Interactions With Other Decision Elements. Time pressure normally affects all other decision elements adversely.

Prerequisites. Training in decision making under time pressure is seen as a logical alternative to decision aiding.

TIME RELAXED DECISION MAKING

General Definition. A decision situation where the decision maker has sufficient time to completely structure the decision in terms of number of attributes, alternatives, states of nature, and outcomes as well as selecting the best alternative. In short, there are no time constraints.

Amplification. The decision making situations where a decision maker has literally "plenty" of time to structure and make a decision represent time relaxed decision making. For example, during the planning phase of an amphibious operation there is plenty of time for discussion and formal reflections on the various possible courses of action which can be adopted.

Rules. There are no specific rules except to be thorough in all aspects of decision structuring and alternative selection. Moreover, there is enough time to conduct sensitivity analyses on alternative selection and decision structuring as well as the quantification process itself.

Pitfalls and Limitations. With sufficient time to make a decision, decision makers often postpone the decision until it is no longer time relaxed. Moreover, if there is too much lead time, the decision situation may change substantially by the time the actual decision is to be made, thereby, negating all the decision-making efforts. There is sometimes a temptation to do something, anything, rather than wait to take action.

Interactions With Other Decision Elements. No major interactions.

Prerequisites. None.

SMALL PROBABILITY/HIGH LOSS DECISION MAKING

General Definition. A situation in which the probabilities associated with the states of nature are very small and the losses associated with the corresponding outcomes very high.

Amplification. Both the probabilities must be small and high for the situation to qualify under this category. Such situations are characterized by the decision maker's lack of familarity, thus rendering the decision "hard". Typical decisions of this type involve the use of nuclear weapons.

Pitfalls and Limitations. One could be enclined to include in this category events with, for example, moderately low probability and very high loss such as loss of life. To avoid this, a specific definition of low and high must be given.

Rules. Identify if the probabilities and losses carry figures out of the usual scale.

Interactions With Other Decision Elements. The major interaction is with the criteria used for risk trade-off analyses as there is experimental evidence that there is utility shift in situations of this type. For instance, in the context of insurance purchasing, people have a tendency to buy more insurance against events having a moderately high probability of inflicting a relatively small loss than against low-probability, high-loss events. In other words, there is a utility shift away from extreme situations, people putting less emphasis on very low probability events even if they carry a very high lost.

Prerequisites. There ought to be a consensus of what is a low probability and what is a high loss in a given decision situation.

NORMAL RANGE DECISION MAKING

General Definition. A situation in which either the probabilities or the losses or both fall within normal range.

Amplification. Only one out of the two elements probability and loss need to fall within normal range for the situation to be normal range. Most decisions in the environment under study are of this nature unless the use of nuclear warfare is specified in the Initiating Directive. Although high losses are usually contemplated such as possible debacle or loss of many lives, the corresponding probabilities, although generally low, do not fall in unusual ranges since such events have occurred in history and the factors causing them examined, thus providing a frame of reference. It is not the case for employment of strategic nuclear weapons for instance or major accident at a nuclear plant.

Pitfalls and Limitations. See comments in small probability/high loss.

Rules. Same as small probability/high loss.

Interactions With Other Decision Elements. No major interactions.

Prerequisites. Same as small probability/high loss.

DECISION EXECUTION

General Definition. A situation in which the decision maker applies a decision solution to a decision problem upon recognition of the current environmental conditions.

Amplification. If the decision problem has been analyzed prior to its actual occurrence and a general solution in terms of reasonably specified procedure has been developed, the responsibility of the operator involved with the decision problem is to "execute" the procedure with the consideration of the problem environmental conditions. A significant number of logistics functions are of the decision-execution type. Formulas and procedures exist allowing one to compute the amount of support which is necessary for each type of mission envisioned.

Rules. Identify the exact role of the decision makers. If they merely apply detailed standard procedures, for example formulas, the decision performed is of the decision execution type.

Pitfalls and Limitations. In certain cases a standard procedure may exist to perform a certain task without constituting a decision solution. The crucial issue is the level of detail in the procedure and consequently certain cases are difficult to decide upon.

Interactions With Other Decision Elements. No major interaction.

Prerequisites. None

DECISION MAKING

General Definition. A situation in which no decision solution is available when the decision problem occurs.

Amplification. The distinction between decision making and decision execution can be defined by the degree of aiding the procedure provides to the decision maker at the time of interaction with the decision problem. However, if such a procedure does not exist, the decision maker will also be responsible for generating the procedure for selecting the decision solution. For time critical decision tasks, the decision-making performance could possibly be increased by shifting the role of the decision maker to decision execution as much as possible. Most decision tasks at MAB level are of the decision-making type.

Rules. Identify the degree of aiding provided by established procedures for task performance and decide if the level of aiding is high (decision execution) or low (decision making).

Pitfalls and Limitations. See comments under decision-execution.

Interactions With Other Decision Elements. No major interaction.

Prerequisites. None.

TYPE I DECISION MAKING

General Definition. A decision which involves only problem structuring.

Amplification. Examples of problem structuring activities are formulation of alternatives and establishment of outcomes. Problem structuring activities generally require a great deal of analysis. An obvious Type I decision task is the generation of friendly courses of action (operations estimate).

Rules. Identify the activities required from the decision maker and classify the decision task accordingly: Type I for problem structuring, Type II for alternative selection, and Type III for problem structuring and alternative selection.

Pitfalls and Limitations. Alternative generation criteria may not be known in advance. Establishment of such criteria may involve both generation of a candidate and selection of the most effective criteria. Therefore, Type I decision tasks may involve lower level Type III decisions.

Interactions With Other Decision Elements. The result may be used by a Type II decision.

Prerequisites. None

TYPE II DECISION MAKING

General Definition. A decision which involves only alternative selection.

Amplification. When a decision problem has been structured, i.e., the alternative set has been defined and the outcome set finalized, an alternative must be chosen. This choice may be made on the basis of assessed utilities and probabilities associated with the decision problem structure already defined. These utilities and probabilities are used for either application of predefined decision rules or to devise and apply alternative selection strategies in order to select an alternative. A typical Type II decision is the comparison of friendly courses of action during the operations estimate.

Rules. See Type I decision making.

Pitfalls and Limitations. Although Type II decisions mostly involve application of predefined decision rules, in some cases rules may not be defined in advance. Therefore, the decision maker's tasks include the generation of a decision rule. In such cases, the effectiveness of the alternative selection process highly depends on the quality of the generated decision rule.

Interactions With Other Decision Elements. A Type I decision task may provide required inputs.

Prerequisites. Alternative courses of action must be known.

TYPE III DECISION MAKING

General Definition. A situation which involves both problem structuring and alternative selection.

Amplification. A Type III decision occurs if it is not possible to decompose the decision task into a problem structuring subtask and an alternative selection subtask, i.e., if the situation is both of Type I and Type II. Most resource allocation decisions are of this nature as the number of possible alternatives is very large and all cannot be formally considered. Instead, an acceptable solution is sought. The task Determine Assault Sequence is one example.

Rules. See Type I decision making.

Pitfalls and Limitations. See Type I and Type II decision making.

Interactions With Other Decision Elements. No major interaction.

Prerequisites. None.

APPENDIX C

FUNCTIONAL REQUIREMENTS

APPENDIX C

FUNCTIONAL REQUIREMENTS

Performance of a number of functions is required when making a decision. This appendix portrays the results of an attempt to describe these functions which are viewed as formal steps a decision maker should go through from a Decision Analysis standpoint.

PROBLEM RECOGNITION

1.1 Recognition of Standards:

Recognition of important problem variables' desired value ranges (or states).

1.2 Identification of Dimensions and Parameters:

Identification of the actual problem variables (i.e., those variables that can cause a transfer from the present state to the desired state by a plausible change in their value). Dimensions refer to the decision variables and their entire range of variability; and parameters refer to the outcome variables (i.e., those factors which although variable, whose values and/or states cannot be directly changed by the decision maker).

1.3 Problem Emergency Criteria and Thresholds:

Identification of the undesirable ranges and/or states of the problem variables as well as the boundaries of desirability for individual variables. Problems will emerge when the value of one or more problem variable falls within undesirable range. The undesirable range of each problem variable may depend on the value of other problem variables. In this case, identification of the nature of such dependency should also be included.

1.4 Comparison of Actual and Desirable States:

Identification of the differences between actual and desirable states in terms of problem variables. Specification of the tolerance level for each problem variable.

1.5 Situation Monitoring Parameters:

Identification of the parameters whose values have a strong correlation with the desired state. These parameters will be used during feedback monitoring. Their value represent an estimate of distance from the desired state.

ALTERNATIVE DEVELOPMENT

2.1 Recognition of Option Existence and Constraints:

Recognition of a soluble decision problem versus an insoluble one. (i.e., recognition of possibility of transforming the present state into the desired state by applying a decision alternative). Identification of constraints on plausible alternatives.

2.2 Establishment of Plausibility Domains:

Identification of the domains of plausible alternatives based on the identified constraints.

2.3 Formulation of Courses of Action:

Composition of plausible courses of action by considering the plausibility domains, problem variables, available resources, etc.

INFORMATION ACQUISITION AND EVALUATION

3.1 Information Purchasing:

Identification of the value of information. Identification of available resources such as time, acquisition power, etc.

3.2 Source Identification and Selection:

Identification of possible sources of information. Evaluation of reliability of each information source. Selection of the most promising source of information.

3.3 Information Ranking:

Identification of the evaluation value of each piece of information along major dimensions such as value of information, reliability of the source, etc. Aggregation of the values of major dimensions and ranking of the pieces of information according to the aggregated results.

3.4 Applying Stopping Rules:

Specification of criteria for sufficiency of information (when to stop seeking and/or purchasing new information and making decisions based on the present information).

3.5 Information Situation Diagnosis:

Identification of each piece of information major attributes such as availability, reliability of the source, cost of acquiring, etc.

ALTERNATIVE EVALUATION/SELECTION

4.1 Criteria Assignment:

Identification and selection of alternative evaluation attributes and criteria.

4.2 Establishing Decision Rules:

Identification and selection of a decision rule such that it embodies the evaluation attributes and criteria as well as the situation monitoring parameters.

4.3 Risks and Probability Assignments:

Identification of the uncertainty and worth points. Assessment of the degree of uncertainty and worth for the corresponding points.

4.4 Analysis of Outcomes and Impacts:

Analysis of the possible decision outcomes and their impacts on the present state, in light of the assessed risks and probabilities.

FEEDBACK MONITORING

5.1 Impact Evaluation:

Evaluation of the impact of each decision outcome in terms of reducing the distance between present state and desired state.

5.2 Recognition of Change:

Identification of changes resulted in problem variables as a result of application of specific courses of action. Identification of the desirable and undesirable effects as well as the undesirable effects beyond the tolerance level.

5.3 Short Range and Long Range Evaluation:

Evaluation of the degree of desirability of the resulting state after application of the course of action (short range). Projection of the effect of the course of action to future and evaluation of the degree of desirability of the future state (long range).